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Tochio

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(54) **DATA RELAY APPARATUS AND FAILURE RECOVERY METHOD**

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(73) Assignee: **Fujitsu Limited**, Kawasaki (JP)

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(51) **Int. Cl.**
H04L 12/26 (2006.01)

(52) **U.S. Cl.** **370/217**; 370/222

(58) **Field of Classification Search** 370/254, 370/352, 401, 351, 256, 252, 400, 216, 222, 370/227, 16, 258, 218, 452; 713/201; 714/717; 359/119; 709/251

See application file for complete search history.

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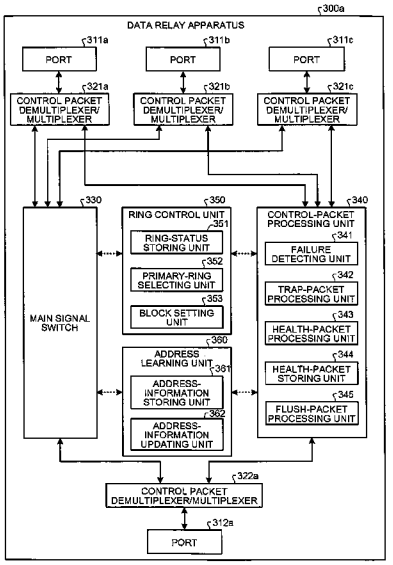
(57) **ABSTRACT**

A data relay apparatus that recovers a failure in a network that shares a part of a plurality of rings and avoids occurrence of a loop path by providing a block in each of the rings includes a failure-notification-packet transmitting unit that transmits, when a failure is detected in a shared portion of a ring, a failure notification packet to a predetermined redundancy-providing ring; and a block setting unit that sets a block that blocks a main signal by passing through a control packet at a port where the failure is detected.

18 Claims, 16 Drawing Sheets



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Japanese Office Action dated Aug. 3, 2010 for Japanese Application No. 2005-092379. A partial English-language translation is provided.

Japanese Office Action mailed May 18, 2010 for Japanese Application No. 2005-092379. A partial English-language translation is provided.

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FIG.1

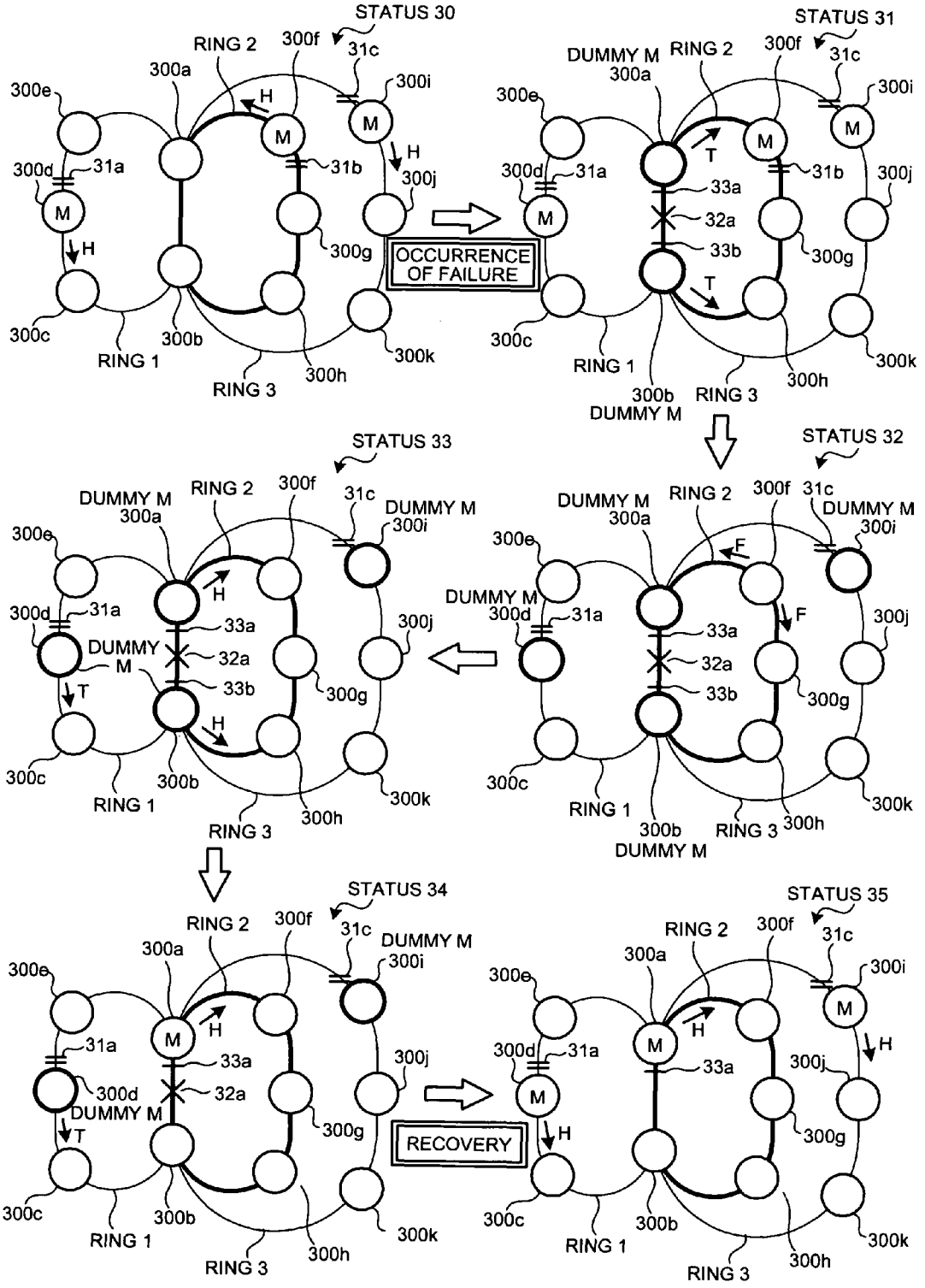

STATUS 30
STATUS 31
STATUS 32
STATUS 33
STATUS 34
STATUS 35
RING 1
RING 2
RING 3
OCCURRENCE OF FAILURE
RECOVERY
DUMMY M
300a
300b
300c
300d
300e
300f
300g
300h
300i
300j
300k
31a
31b
31c
32a
33a
33b
H
T
F
M

FIG.2

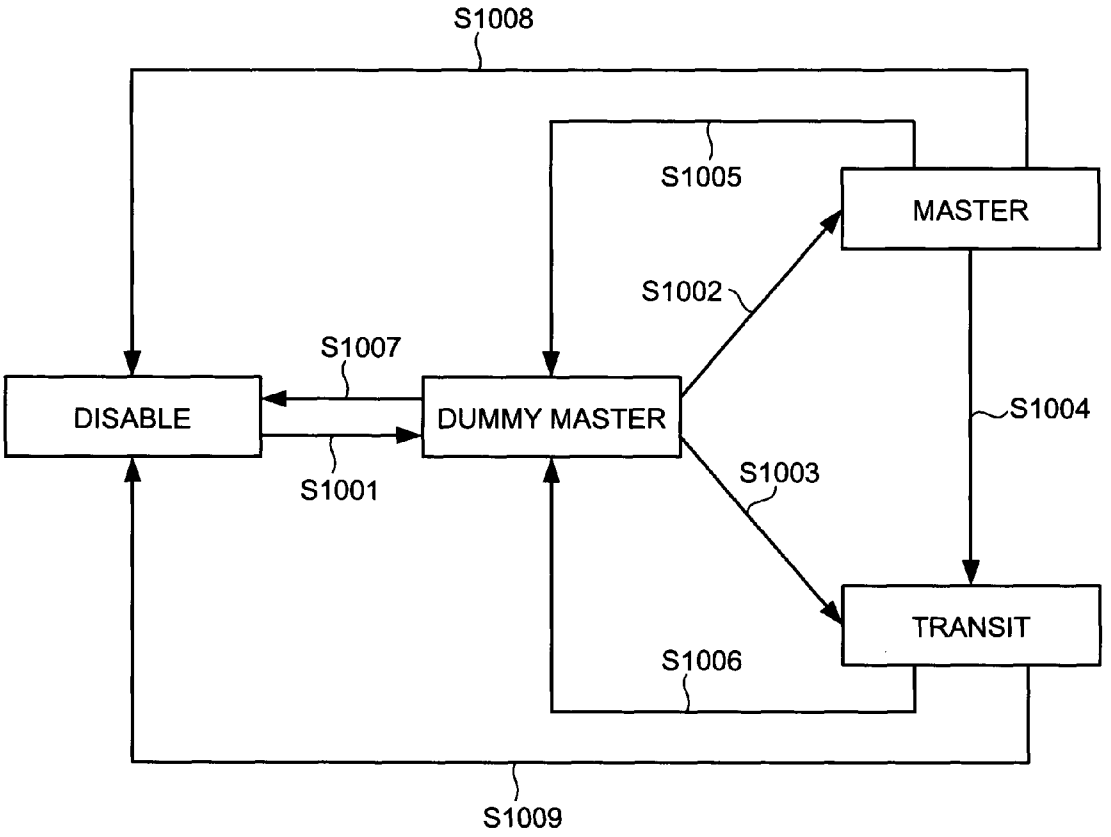

S1008
S1005
MASTER
S1002
S1007
DISABLE
DUMMY MASTER
S1004
S1001
S1003
TRANSIT
S1006
S1009

FIG.3

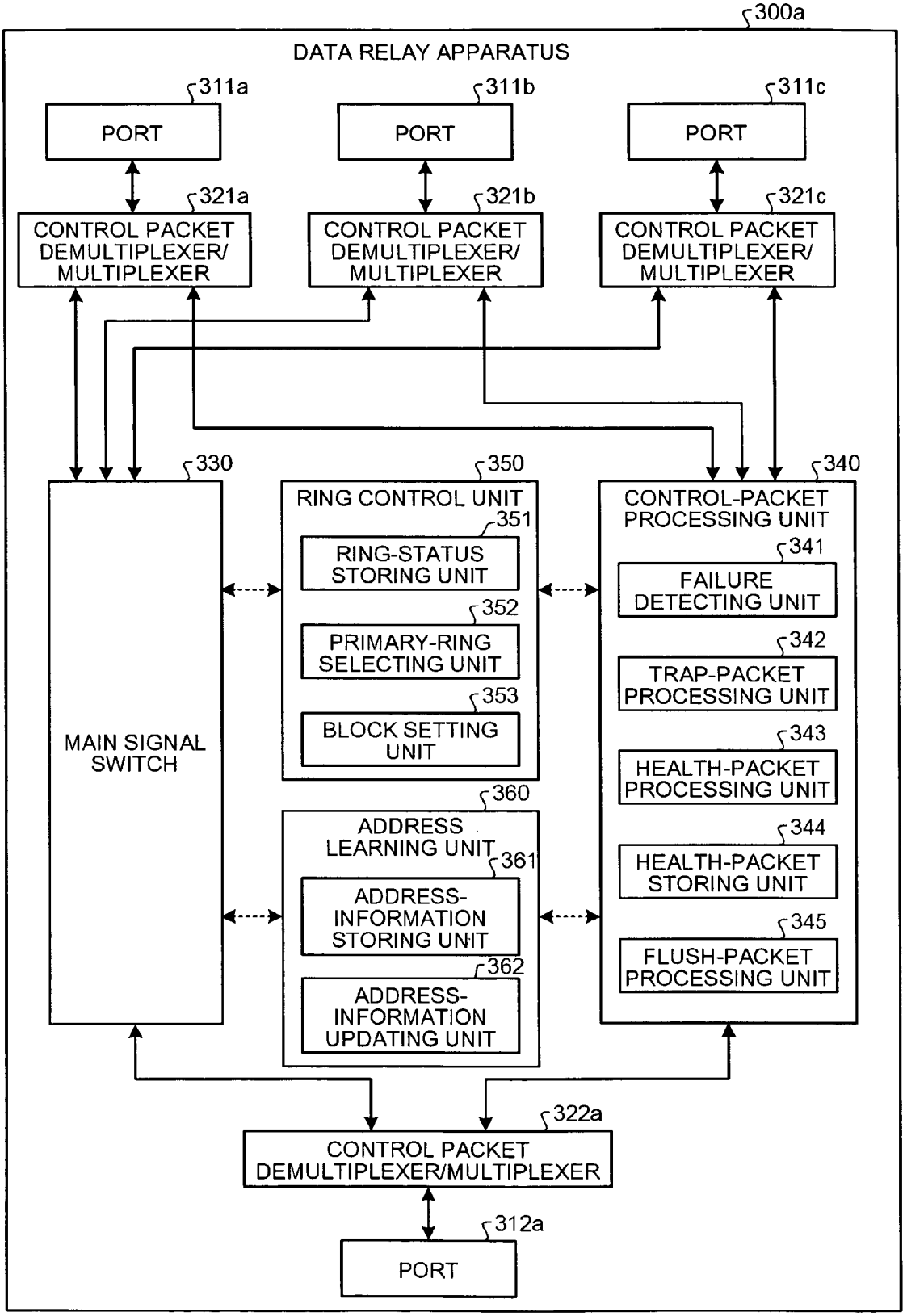

300a
DATA RELAY APPARATUS
311a
PORT
311b
PORT
311c
PORT
321a
CONTROL PACKET DEMULTIPLEXER/ MULTIPLEXER
321b
CONTROL PACKET DEMULTIPLEXER/ MULTIPLEXER
321c
CONTROL PACKET DEMULTIPLEXER/ MULTIPLEXER
330
MAIN SIGNAL SWITCH
350
RING CONTROL UNIT
351
RING-STATUS STORING UNIT
352
PRIMARY-RING SELECTING UNIT
353
BLOCK SETTING UNIT
360
ADDRESS LEARNING UNIT
361
ADDRESS-INFORMATION STORING UNIT
362
ADDRESS-INFORMATION UPDATING UNIT
340
CONTROL-PACKET PROCESSING UNIT
341
FAILURE DETECTING UNIT
342
TRAP-PACKET PROCESSING UNIT
343
HEALTH-PACKET PROCESSING UNIT
344
HEALTH-PACKET STORING UNIT
345
FLUSH-PACKET PROCESSING UNIT
322a
CONTROL PACKET DEMULTIPLEXER/MULTIPLEXER
312a
PORT

FIG.4

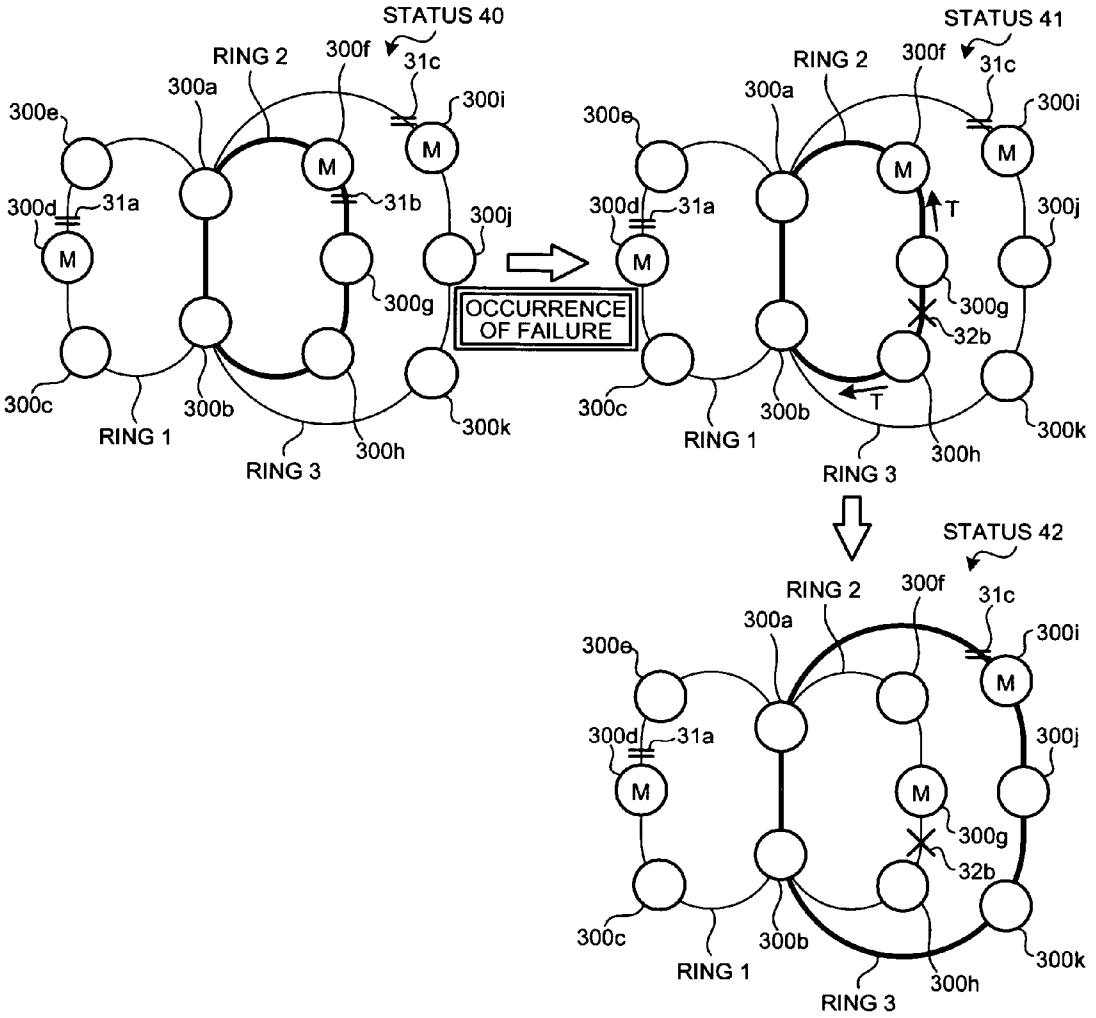

STATUS 40
RING 2
300f
31c
300a
300i
300e
M
M
M
300d
31a
31b
300j
300g
OCCURRENCE OF FAILURE
300c
RING 1
300b
300k
RING 3
300h
STATUS 41
T
32b
STATUS 42

FIG.5

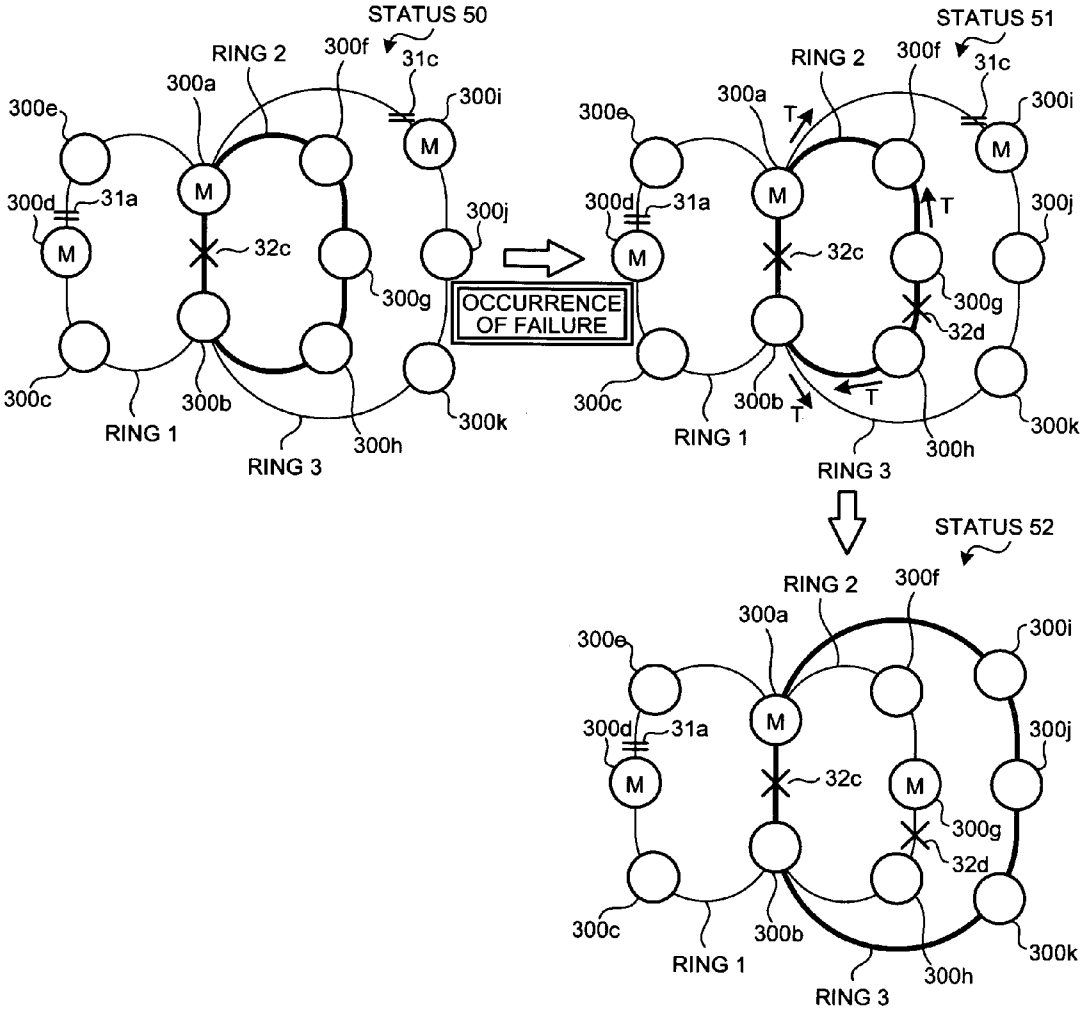

STATUS 50
RING 2
300f
31c
300a
300i
300e
M
300d
31a
M
32c
300j
M
300g
OCCURRENCE OF FAILURE
300c
300b
300k
RING 1
300h
RING 3
STATUS 51
RING 2
300f
31c
300a
T
300i
300e
M
300d
31a
M
T
300j
M
32c
300g
32d
T
T
300c
300b
T
300k
RING 1
300h
RING 3
STATUS 52
RING 2
300f
300a
300i
300e
M
300d
31a
300j
M
32c
M
300g
32d
300c
300b
300k
RING 1
300h
RING 3

FIG.6

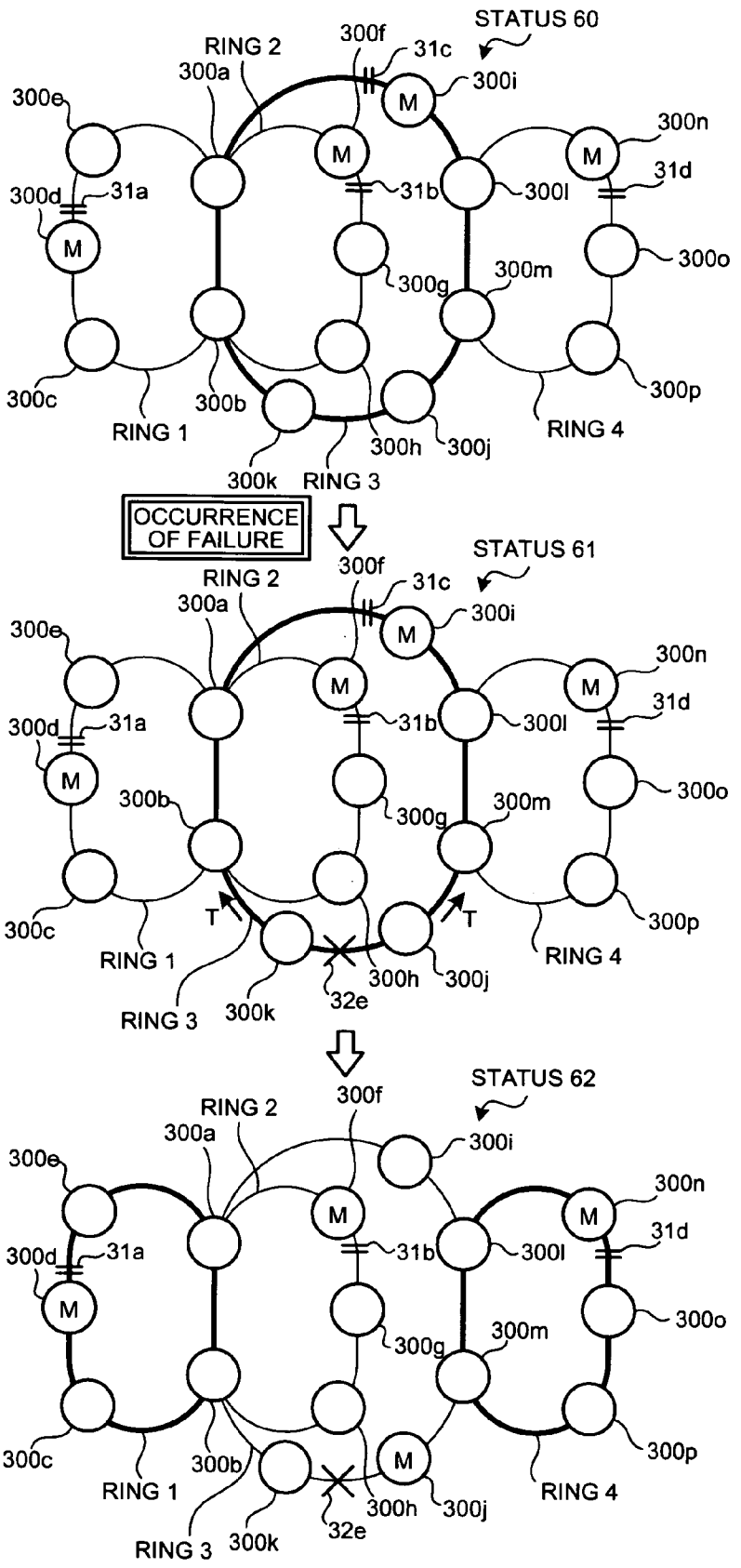

STATUS 60
RING 2
300a
300f
31c
300i
300e
M
300n
M
M
31d
300d
31a
31b
300l
M
300o
300g
300m
300c
300b
300p
RING 1
300h
300j
RING 4
300k
RING 3
OCCURRENCE OF FAILURE
STATUS 61
RING 2
300a
300f
31c
300i
300e
M
300n
M
M
31d
300d
31a
31b
300l
M
300o
300b
300g
300m
T
T
300c
300p
RING 1
300h
300j
RING 4
RING 3
300k
32e
STATUS 62
300f
RING 2
300a
300i
300e
M
300n
M
M
31d
300d
31a
31b
300l
M
300o
300g
300m
300c
300b
M
300p
RING 1
300h
300j
RING 4
32e
RING 3
300k

FIG.7

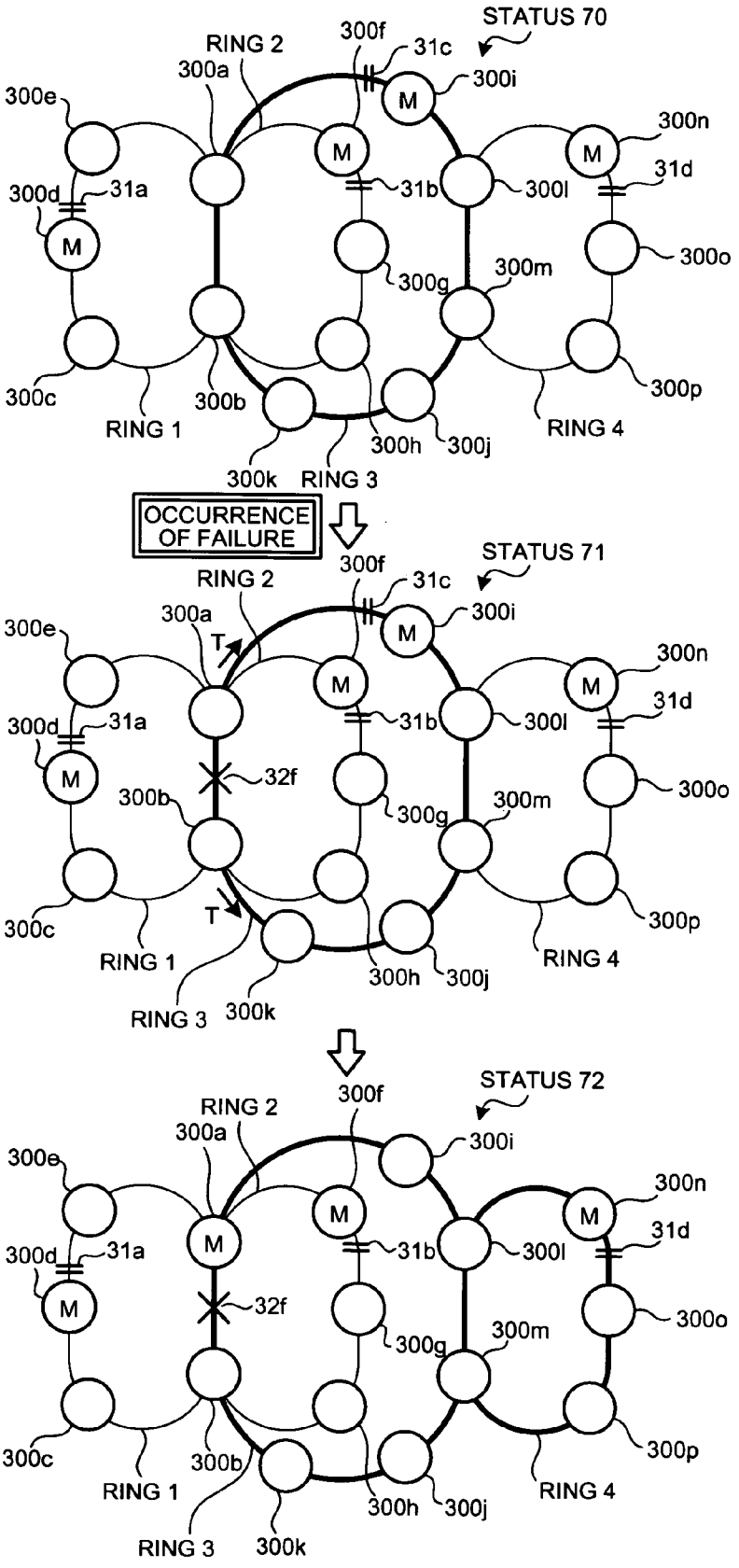

STATUS 70
RING 2
300a
300f
31c
300i
300e
M
300n
31d
300d
31a
31b
300l
300o
300g
300m
300c
300b
300p
RING 1
300h
300j
RING 4
300k
RING 3
OCCURRENCE OF FAILURE
STATUS 71
T
32f
STATUS 72

FIG.8

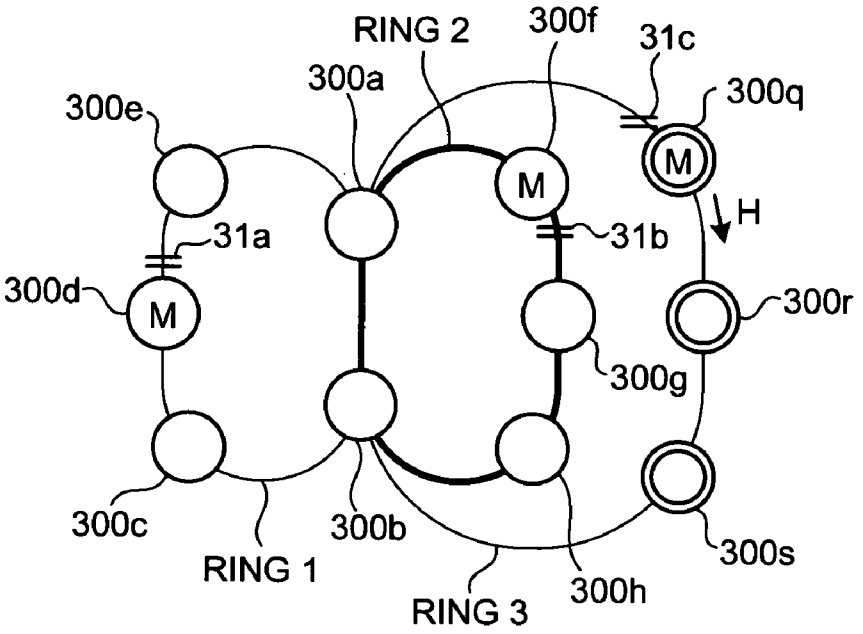

RING 2
300f
31c
300a
300q
300e
M
M
H
31a
31b
300d
M
300r
300g
300c
300b
300s
RING 1
300h
RING 3

FIG.9

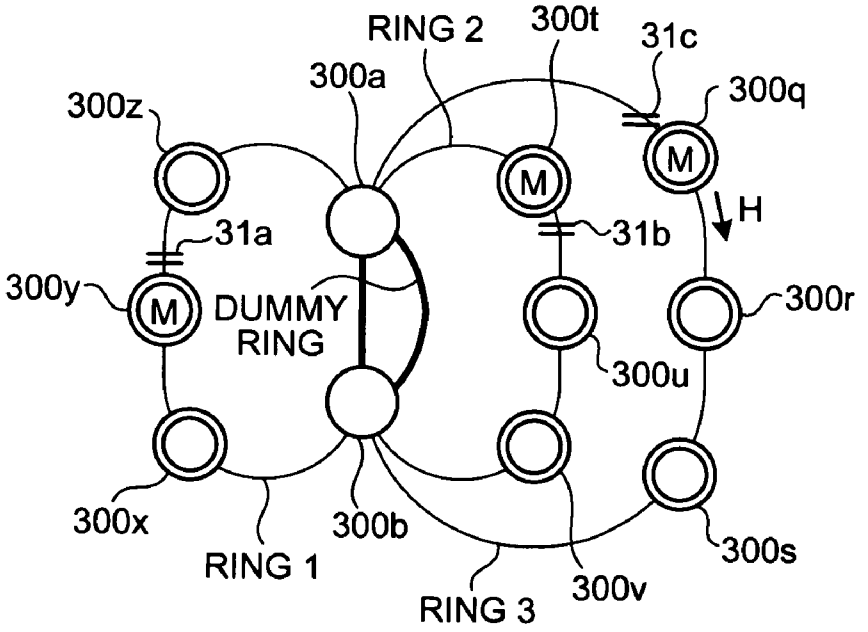

RING 2
300t
31c
300a
300q
300z
M
M
H
31a
31b
300y
M
DUMMY
RING
300r
300u
300x
300b
300s
RING 1
300v
RING 3

FIG.10

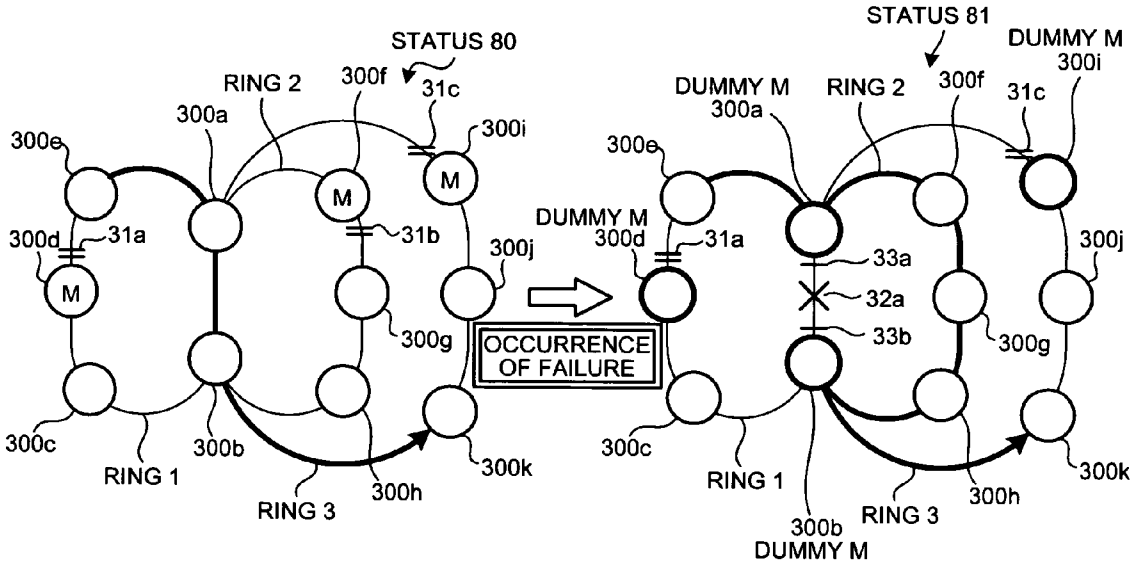

STATUS 80
RING 2
300f
31c
300a
300i
300e
M
M
300d
31a
31b
M
300j
300g
OCCURRENCE OF FAILURE
300c
300b
300k
RING 1
RING 3
300h
STATUS 81
DUMMY M
300i
DUMMY M
300a
RING 2
300f
31c
300e
DUMMY M
300d
31a
33a
32a
33b
300j
300g
300c
RING 1
300b
DUMMY M
RING 3
300h
300k

FIG.11

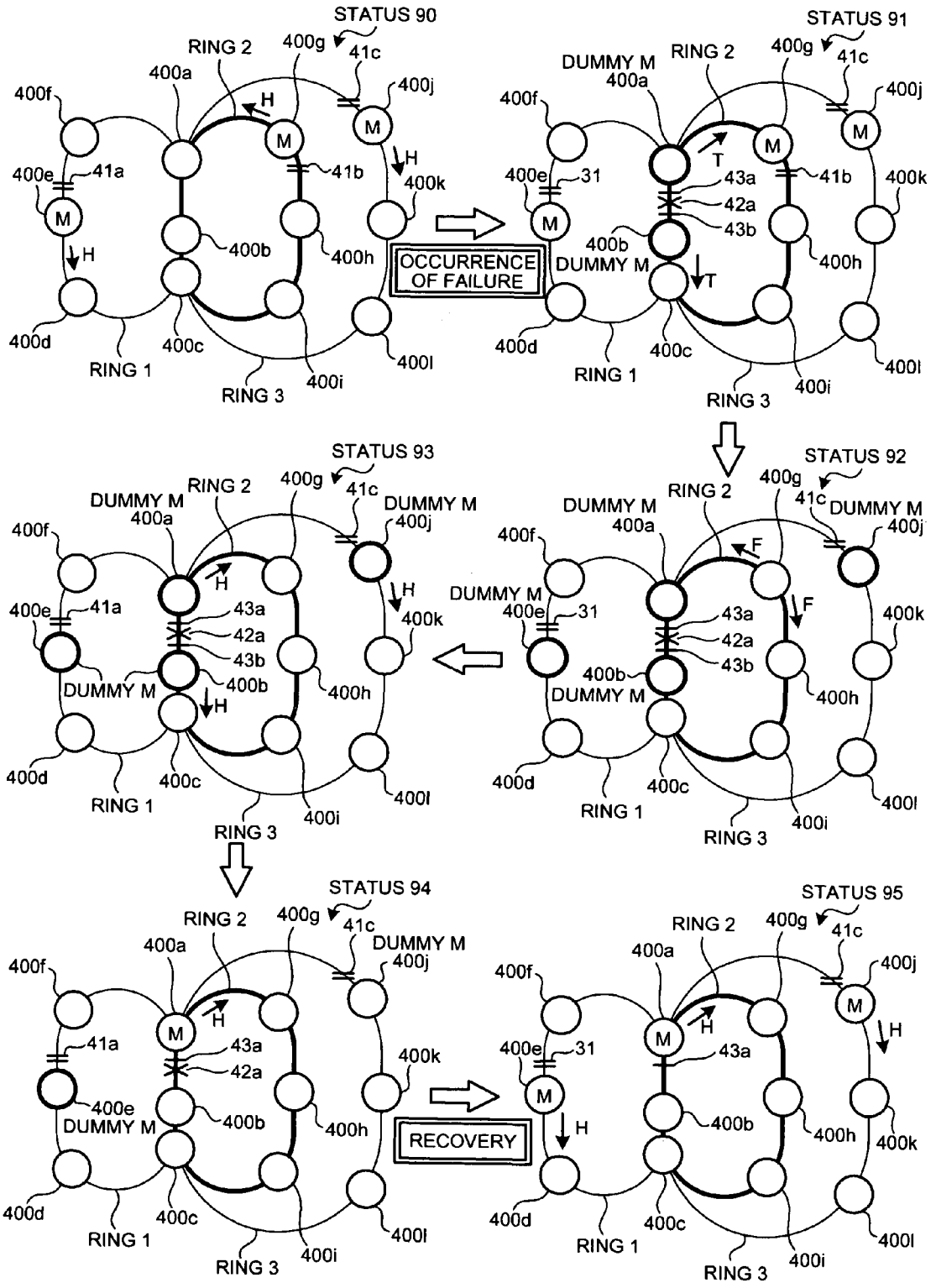

STATUS 90
RING 2
400g
41c
400a
400j
400f
H
M
400e
41a
41b
400k
400b
400h
OCCURRENCE OF FAILURE
400d
400c
400l
RING 1
RING 3
400i
STATUS 91
DUMMY M
T
31
43a
42a
43b
STATUS 92
F
STATUS 93
STATUS 94
RECOVERY
STATUS 95

FIG.12

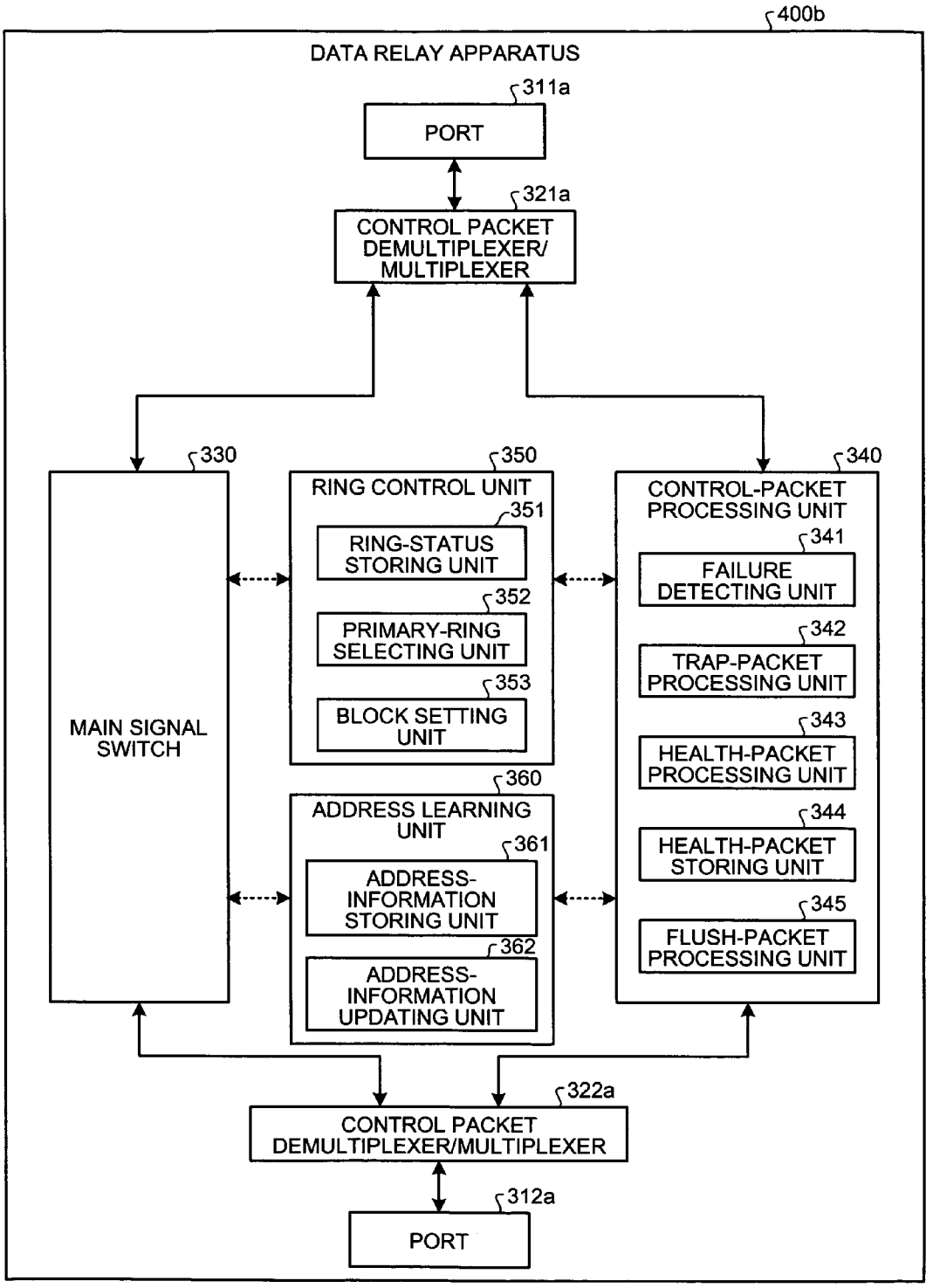

400b
DATA RELAY APPARATUS
311a
PORT
321a
CONTROL PACKET DEMULTIPLEXER/ MULTIPLEXER
330
MAIN SIGNAL SWITCH
350
RING CONTROL UNIT
351
RING-STATUS STORING UNIT
352
PRIMARY-RING SELECTING UNIT
353
BLOCK SETTING UNIT
360
ADDRESS LEARNING UNIT
361
ADDRESS-INFORMATION STORING UNIT
362
ADDRESS-INFORMATION UPDATING UNIT
340
CONTROL-PACKET PROCESSING UNIT
341
FAILURE DETECTING UNIT
342
TRAP-PACKET PROCESSING UNIT
343
HEALTH-PACKET PROCESSING UNIT
344
HEALTH-PACKET STORING UNIT
345
FLUSH-PACKET PROCESSING UNIT
322a
CONTROL PACKET DEMULTIPLEXER/MULTIPLEXER
312a
PORT

FIG.13

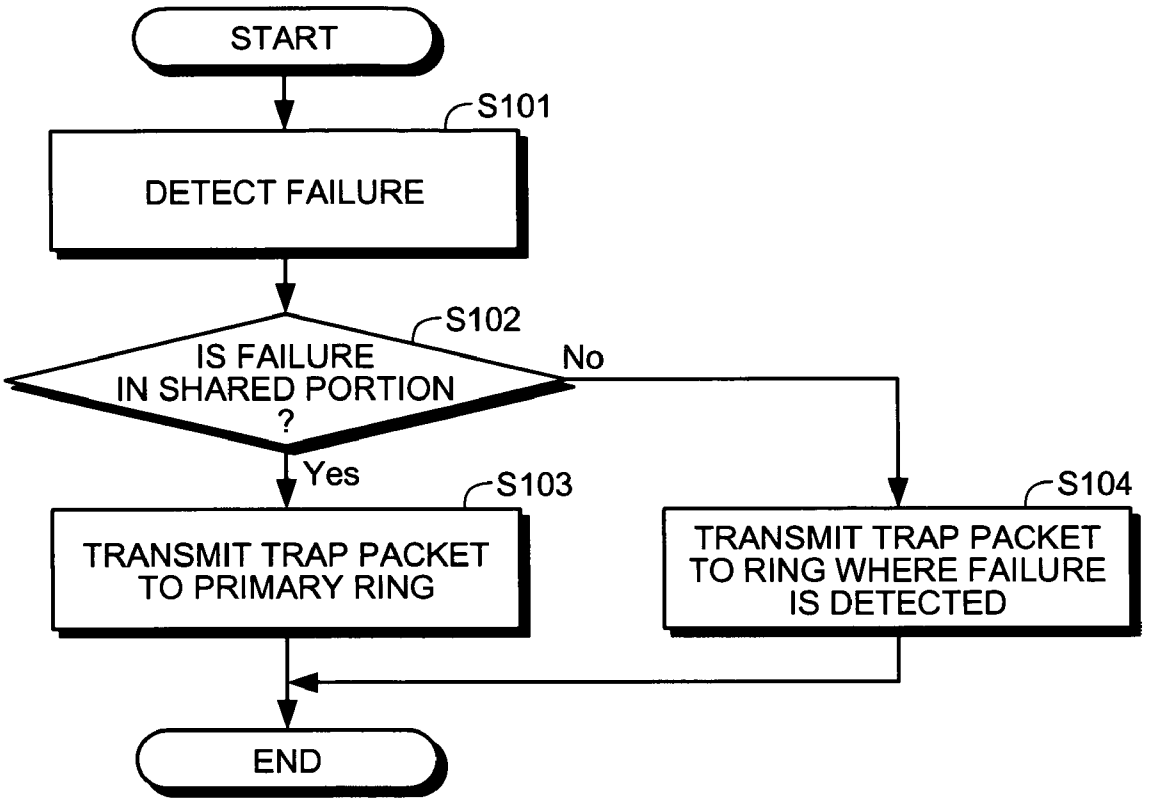

START
S101
DETECT FAILURE
S102
IS FAILURE IN SHARED PORTION ?
No
Yes
S103
TRANSMIT TRAP PACKET TO PRIMARY RING
S104
TRANSMIT TRAP PACKET TO RING WHERE FAILURE IS DETECTED
END

FIG.14

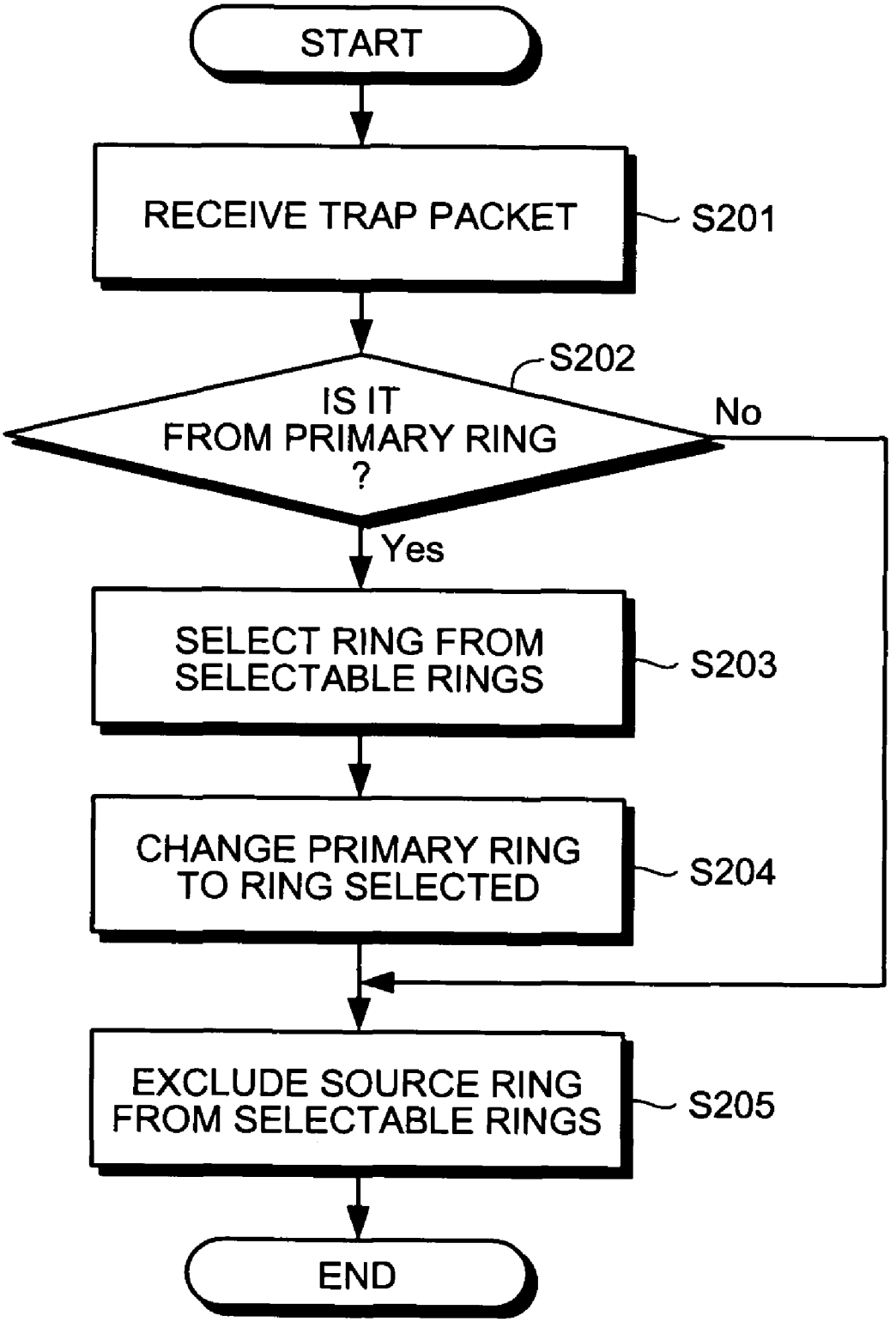

START
RECEIVE TRAP PACKET
S201
S202
IS IT FROM PRIMARY RING ?
No
Yes
SELECT RING FROM SELECTABLE RINGS
S203
CHANGE PRIMARY RING TO RING SELECTED
S204
EXCLUDE SOURCE RING FROM SELECTABLE RINGS
S205
END

FIG.15

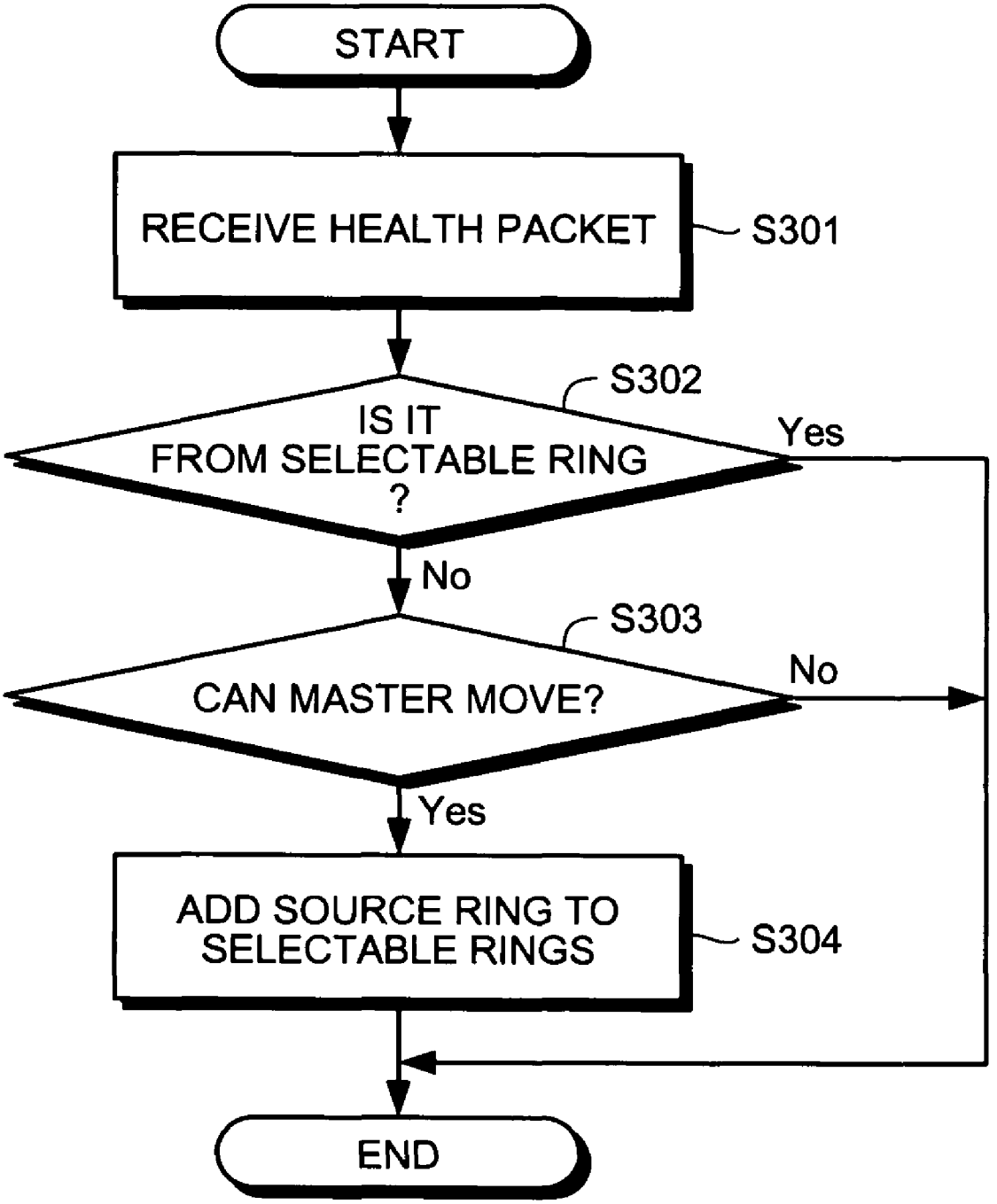

START
RECEIVE HEALTH PACKET
S301
S302
IS IT FROM SELECTABLE RING ?
Yes
No
S303
CAN MASTER MOVE?
No
Yes
ADD SOURCE RING TO SELECTABLE RINGS
S304
END

FIG.16

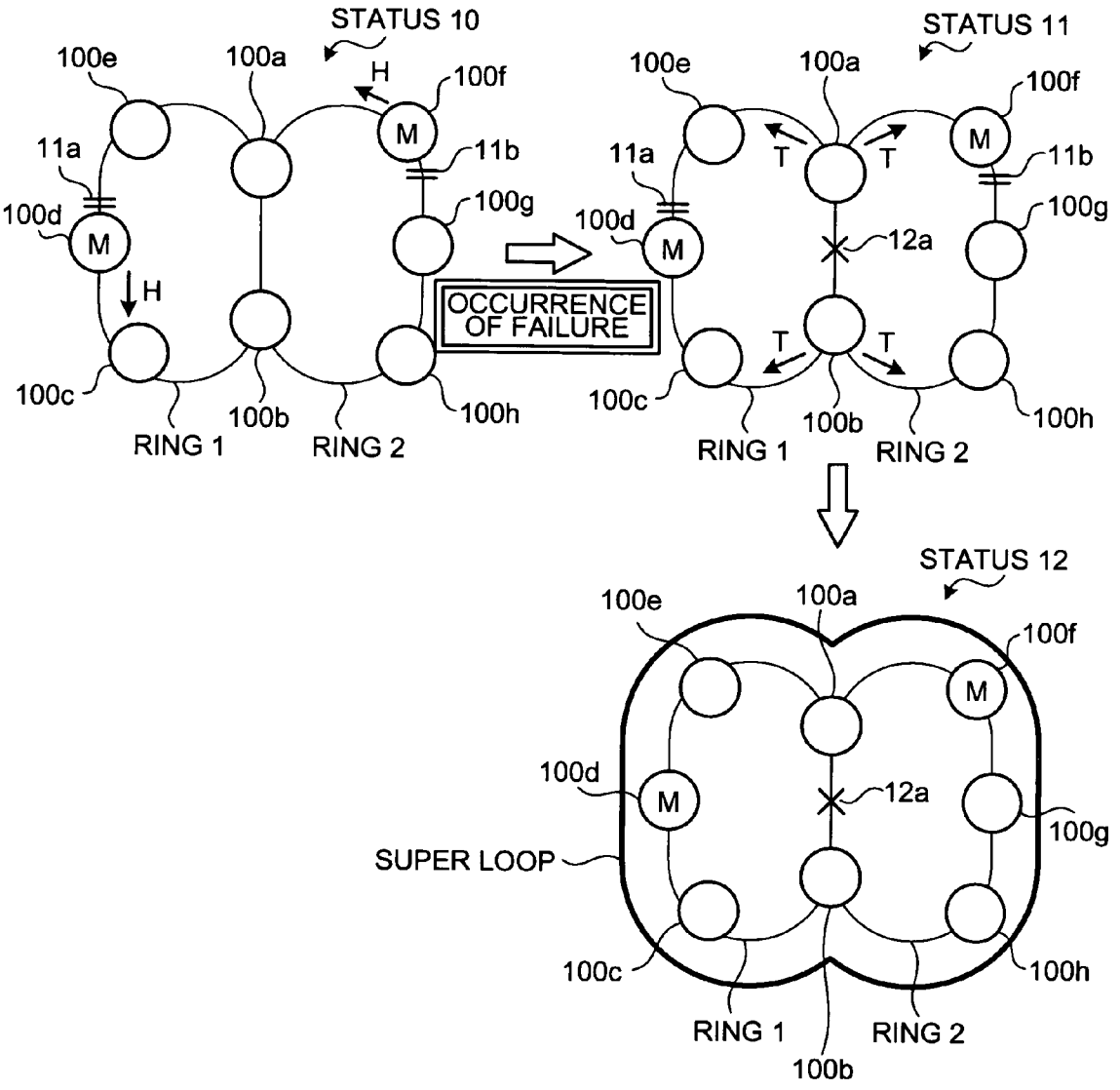
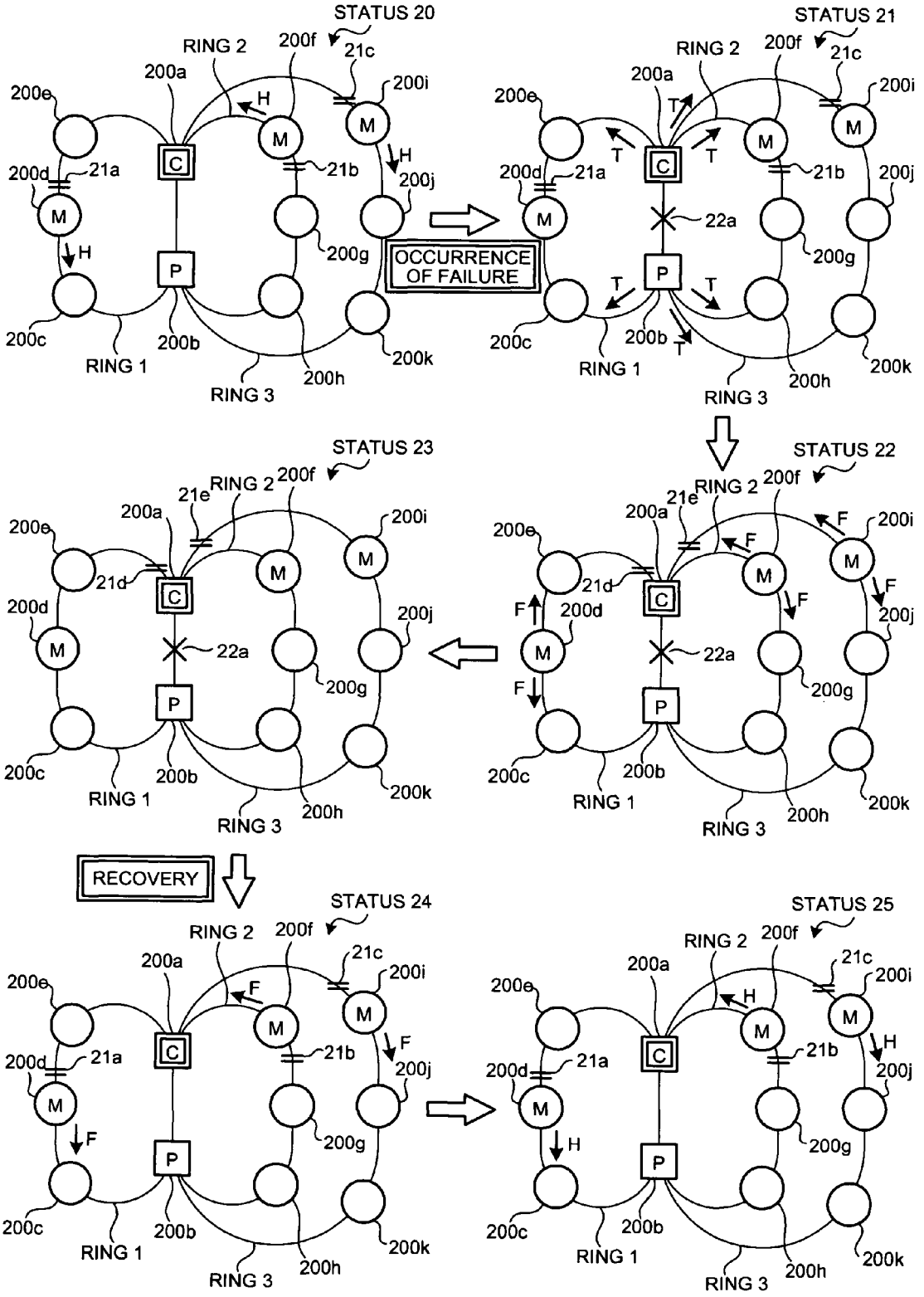

STATUS 10
100e
100a
H
100f
M
11a
11b
100d
100g
M
H
OCCURRENCE OF FAILURE
100c
100b
100h
RING 1
RING 2
STATUS 11
100e
100a
100f
T
T
M
11a
11b
100d
100g
M
12a
T
T
100c
100b
100h
RING 1
RING 2
STATUS 12
100e
100a
100f
M
100d
M
12a
100g
SUPER LOOP
100c
100h
RING 1
RING 2
100b

FIG.17


STATUS 20
STATUS 21
STATUS 22
STATUS 23
STATUS 24
STATUS 25
OCCURRENCE OF FAILURE
RECOVERY
RING 1
RING 2
RING 3
200a
200b
200c
200d
200e
200f
200g
200h
200i
200j
200k
21a
21b
21c
21d
21e
22a
C
P
M
H
T
F

DATA RELAY APPARATUS AND FAILURE RECOVERY METHOD

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a technology for recovering a failure in a network that shares a part of a plurality of rings and avoids occurrence of a loop path by providing a block in each of the rings.

2. Description of the Related Art

Recently, a network based on layer **2** using Ethernet (TM) is often used for building a large scale network such as a wide area network. The network using Ethernet (TM) has such advantages that its introduction cost is comparatively low but high-speed communication can be achieved.

When a large scale network is built using Ethernet (TM), how to ensure redundancy is a significant matter. Because Ethernet (TM) has been developed specifically for a small scale network such as a local area network (LAN) and has therefore no redundancy that is required for the large scale network.

One of technologies of providing redundancy to the network based on Ethernet (TM) is Ethernet (TM) Automatic Protection Switching (EAPS). This is a technology specific to a loop topology, and high-speed failure recovery is thereby achieved. EAPS selects one of data relay apparatuses, as a master, connected to one another in a ring shape (a data relay apparatus other than "master" is called "transit"), and suppresses occurrence of a loop of packets by blocking one port by the master. The network is restored by releasing the port upon occurrence of a failure (see S. Shah, M. Yip, "Extreme Networks' Ethernet (TM) Automatic Protection Switching (EAPS) Version 1", [online], October 2003, retrieved from the Internet:
<URL:http://www.ietf.org/rfc/rfc3619.txt>).

Japanese Patent Application 2004-076593 discloses a technology of improving EAPS. This technology is used when a failure occurs, and it is used so as to prevent occurrence of communication interruption upon failure recovery by re-selecting a data relay apparatus, as a master, provided adjacent to a location where the failure occurs. PCT/JP2005/000143 discloses a technology of efficiently performing the process of re-selecting a master in Japanese Patent Application 2004-076593.

In EAPS version 2 (EAPS v2) that is extended specifications of EAPS, redundancy in a multi-ring structure is also ensured. When a plurality of loop-type networks are caused to have a shared portion to form a multi-ring structure, so-called a super loop may be formed if a failure occurs in the shared portion, and a loop of packets may stop the network.

To solve the problems, in EAPS v2, a role as a controller or as a partner is given to the data relay apparatus in a shared portion. If a failure occurs in the shared portion, then the controller keeps only one of ports on the opposite side to a location where the failure occurs, and suppresses formation of the super loop by blocking other ports (see "Solution Guide", [online], retrieved from the Internet:
<URL:http://www.extremenetworks.co.jp/solutions/enterprise_solution/solution_guide/index.htm>).

In the system of EAPS v2, however, it is necessary to control data relay apparatuses by using their roles that includes four types in total obtained by adding roles of a controller and a partner to the master and the transit. Therefore, the load for the control increases. Furthermore, a position of the block largely changes when the failure occurs and the failure is recovered, which causes communication interruption to occur over the whole network.

SUMMARY OF THE INVENTION

It is an object of the present invention to at least solve the problems in the conventional technology.

A data relay apparatus according to one aspect of the present invention, which recovers a failure in a network that shares a part of a plurality of rings and avoids occurrence of a loop path by providing a block in each of the rings, includes a failure-notification-packet transmitting unit that transmits, when a failure is detected in a shared portion of a ring, a failure notification packet to a predetermined redundancy-providing ring; and a block setting unit that sets a block that blocks a main signal by passing through a control packet at a port where the failure is detected.

A failure recovery method according to another aspect of the present invention, which is for a data relay apparatus that recovers a failure in a network that shares a part of a plurality of rings and avoids occurrence of a loop path by providing a block in each of the rings, includes transmitting, when a failure is detected in a shared portion of a ring, a failure notification packet to a predetermined redundancy-providing ring; and setting a block that blocks a main signal by passing through a control packet at a port where the failure is detected.

The above and other objects, features, advantages and technical and industrial significance of this invention will be better understood by reading the following detailed description of presently preferred embodiments of the invention, when considered in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic for explaining an overview of a failure recovery method according to the present invention;

FIG. **2** is a schematic for illustrating a status transition of a data relay apparatus;

FIG. **3** is a block diagram of a configuration of the data relay apparatus shown in FIG. **1**;

FIG. **4** is a schematic for explaining how to address a case where a failure occurs in a non-shared portion of a primary ring;

FIG. **5** is a schematic for explaining how to address a case where failures occur in a shared portion and a non-shared portion of the primary ring;

FIG. **6** is a schematic for explaining how to address a case where a plurality of shared portions is present in the primary ring;

FIG. **7** is a schematic for explaining how to address another case where a plurality of shared portions is present in the primary ring;

FIG. **8** is a schematic for explaining how to address a case where there is a ring based on EAPS;

FIG. **9** is a schematic for explaining how to address a case where all the rings are based on EAPS;

FIG. **10** is a schematic for explaining how to update address information;

FIG. **11** is a schematic for explaining failure recovery operation when three or more data relay apparatuses are provided in the shared portion;

FIG. **12** is a block diagram of a configuration of a data relay apparatus shown in FIG. **11**;

FIG. **13** is a flowchart of process procedures for a case where a failure is detected;

FIG. **14** is a flowchart of process procedures for a case where a trap packet is received;

FIG. **15** is a flowchart of process procedures for a case where a health packet is received;

FIG. **16** is a schematic for explaining some problems when a failure occurs in a shared portion of a ring; and

FIG. **17** is a schematic for explaining an overview of a conventional failure recovery method.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Exemplary embodiments of a data relay apparatus and a failure recovery method according to the present invention are explained in detail below with reference to the accompanying drawings.

Some problems occurring when a failure occurs in a shared portion of a multi-ring network are explained below. FIG. **16** is a schematic for explaining some problems when a failure occurs in a shared portion of a ring.

The network shown in FIG. **16** has a multi-ring structure that shares a portion between a data relay apparatus **100***a* and a data relay apparatus **100***b* based on a ring **1** that includes the data relay apparatuses **100***a* and **100***b* and data relay apparatuses **100***c*, **100***d*, and **100***e*; and a ring **2** that includes the data relay apparatuses **100***a* and **100***b* and data relay apparatuses **100***f*, **100***g*, and **100***h*.

In normal operation, the data relay apparatus **100***d* that is a master (M) of the ring **1** sets a block **11***a* in a port thereof on the side of the data relay apparatus **100***e*, and causes a health (H) packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **100***f* that is a master of the ring **2** sets a block **11***b* in a port thereof on the side of the data relay apparatus **100***g*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring (status **10**).

Assume that a failure **12***a* occurs in a portion between the data relay apparatuses **100***a* and **100***b* that is a shared portion. The data relay apparatuses **100***a* and **100***b* detect the failure **12***a* to send "trap" packets (T) for notification of occurrence of the failure to both the ring **1** and the ring **2** (status **11**). The data relay apparatuses **100***d* and **100***f* that are the masters receive the trap packets to release the block **11***a* and the block **11***b* respectively in order to recover the failure. As a result, a loop covering the ring **1** and ring **2**, a so-called super loop is formed (status **12**).

Formation of the super loop causes packets of user data that are broadcast to be increased and a bandwidth to be thereby compressed, and the network to be finally down. This problem occurs not only in the network based on EAPS but also in a network based on the technology according to Patent Literature 1 and a network based on the technology according to Patent Literature 2.

A conventional failure recovery method (specifically, a method of EAPS v2) for preventing formation of the super loop is explained below. FIG. **17** is a schematic for explaining an overview of the conventional failure recovery method.

The network shown in FIG. **17** has a multi-ring structure that shares a portion between a data relay apparatus **200***a* and a data relay apparatus **200***b* based on a ring **1** that includes the data relay apparatuses **200***a* and **200***b* and data relay apparatuses **200***c*, **200***d*, and **200***e*; a ring **2** that includes the data relay apparatuses **200***a* and **200***b* and data relay apparatuses **200***f*, **200***g*, and **200***h*; and a ring **3** that includes the data relay apparatuses **200***a* and **200***b* and data relay apparatuses **200***i*, **200***j*, and **200***k*.

A role as a controller (C) is allocated to the data relay apparatus **200***a* in the shared portion, and a role as a partner (P) is allocated to the other data relay apparatus **200***b* in the shared portion. When a failure occurs in the shared portion, the controller takes measures to prevent formation of the super loop.

In normal operation, the data relay apparatus **200***d* that is a master of the ring **1** sets a block **21***a* in a port thereof on the side of the data relay apparatus **200***e*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **200***f* that is a master of the ring **2** sets a block **21***b* in a port thereof on the side of the data relay apparatus **200***g*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **200***i* that is a master of the ring **3** sets a block **21***c* in a port thereof on the side of the data relay apparatus **200***a*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring (status **20**).

Assume that a failure **22***a* occurs in a portion between the data relay apparatuses **200***a* and **200***b* that is the shared portion. The data relay apparatuses **200***a* and **200***b* detect the failure **22***a* to send trap packets for notification of occurrence of the failure to the ring **1**, the ring **2**, and the ring **3** (status **21**).

The data relay apparatus **200***a* that is the controller releases ports on the side where the failure is detected except one port on the opposite side thereto after transmission of the trap packets. In this example, the port connected to the ring **2** is left as it is, a block **21***d* is set in a port connected to the ring **1**, and a block **21***e* is set in a port connected to the ring **3**.

When receiving the trap packets, the data relay apparatus **200***d*, the data relay apparatus **200***f*, and the data relay apparatus **200***i* that are the masters release the block **21***a*, the block **21***b*, and the block **21***c*, respectively, to recover the failure. The release of these blocks causes a communication path to be changed. Therefore, the data relay apparatus **200***d*, the data relay apparatus **200***f*, and the data relay apparatus **200***i* transmit "flush" packets (F) to the data relay apparatuses in the respective rings, instructing them to flush address information learned.

Even if the data relay apparatus **200***d*, the data relay apparatus **200***f*, and the data relay apparatus **200***i* release the block **21***a* to the block **21***c* in the above manner, the super loop is prevented from its formation because the data relay apparatus **200***a* sets the block **21***d* and the block **21***e*. Furthermore, the data relay apparatus **200***a* does not set a block in the ring **2**. Therefore, the ring **2** can be used as an alternative to the portion between the data relay apparatuses **200***a* and **200***b* where the failure occurs (status **23**).

When the failure is recovered, the data relay apparatus **200***a* releases the block **21***d* and the block **21***e*, and the data relay apparatus **200***d*, the data relay apparatus **200***f*, and the data relay apparatus **200***i* re-set the block **21***a*, the block **21***b*, and the block **21***c*, respectively. By releasing and re-setting these blocks, the communication path is changed. Therefore, the data relay apparatus **200***d*, the data relay apparatus **200***f*, and the data relay apparatus **200***i* also transmit the flush packets to the data relay apparatuses, instructing them to flush the address information learned (status **24**).

Thereafter, the data relay apparatus **200***d*, the data relay apparatus **200***f*, and the data relay apparatus **200***i* restart transmission of the health packets, and then the network returns to the normal status (status **25**).

Even in the conventional failure recovery method, it is also possible to prevent formation of the super loop when the failure occurs in the shared portion. In this method, however,

it is necessary to allocate the four roles such as the master, the transit, the controller, and the partner to the data relay apparatuses that form the network, respectively, which causes the load for control of these roles to increase. Furthermore, all the data relay apparatuses re-learn the address information in the scene of status **22** and the scene of status **24**, which causes the communication interruption over the network to occur twice.

The failure recovery method according to the present invention is explained below. FIG. **1** is a schematic for explaining an overview of the failure recovery method according to the present invention.

The network shown in FIG. **1** has a multi-ring structure that shares a portion between a data relay apparatus **300***a* and a data relay apparatus **300***b* based on a ring **1** that includes the data relay apparatuses **300***a* and **300***b* and data relay apparatuses **300***c*, **300***d*, and **300***e*; a ring **2** that includes the data relay apparatuses **300***a* and **300***b* and data relay apparatuses **300***f*, **300***g*, and **300***h*; and a ring **3** that includes the data relay apparatuses **300***a* and **300***b* and data relay apparatuses **300***i*, **300***j*, and **300***k*.

The data relay apparatus **300***a* and the data relay apparatus **300***b* situated in a shared portion are data relay apparatuses that execute the failure recovery method according to the present invention. The other data relay apparatuses are ones that perform failure recovery based on the technology of Patent Literature 2. The failure recovery method according to the present invention can also be executed based on the technology of Patent Literature 1 or based on the technology of Patent Literature 2, but here, the failure recovery method according to the present invention based on the technology of Patent Literature 2 is explained below.

In the failure recovery method according to the present invention, one of rings that share a shared portion is selected, and this ring selected is handled as a primary ring. The primary ring provides redundancy when a failure occurs in the shared portion. In this example, the ring **2** is selected as the primary ring. Initial selection of the primary ring may be performed by an administrator, or a data relay apparatus in the shared portion may perform the initial selection autonomously.

In normal operation, the data relay apparatus **300***d* that is a master of the ring **1** sets a block **31***a* in a port thereof on the side of the data relay apparatus **300***e*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **300***f* that is a master of the ring **2** sets a block **31***b* in a port thereof on the side of the data relay apparatus **300***g*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **300***i* that is a master of the ring **3** sets a block **31***c* in a port thereof on the side of the data relay apparatus **300***a*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring (status **30**).

Assume that a failure **32***a* occurs in a portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* that is a shared portion. The data relay apparatus **300***a* detects the failure **32***a*, and determines whether the failure **32***a* occurs in the shared portion. If it is determined that it occurs in the shared portion, the data relay apparatus **300***a* sets a block **33***a* in a port thereof on the shared portion side and sends a trap packet only from a port, out of ports on the opposite side to the shared portion, connected to the ring **2** that is the primary ring. Likewise, the data relay apparatus **300***b* sets a block **33***b* in a port thereof on the shared portion side and sends a trap packet only from a port, out of ports on the opposite side to the shared portion, connected to the ring **2**. The block **33***a* and the block **33***b* block a user data packet but allow a control packet such as a health packet to pass through the ports.

The data relay apparatus **300***a* and the data relay apparatus **300***b* move to dummy masters after transmission of the trap packets. The movement of a data relay apparatus that detects a failure to the dummy master after the transmission of the trap packet thereby is normal operation when the failure recovery is performed based on the technology of Patent Literature 2.

When receiving the trap packet, the data relay apparatus **300***f* that is a master of the ring **2** releases the block **31***b* to recover the failure, and then moves to the transit. The movement of the master that receives the trap packet to the transit is normal operation when the failure recovery is performed based on the technology of Patent Literature 2.

The release of the block **31***b* causes a communication path to be changed. Therefore, the data relay apparatus **200***f* transmits flush packets to the data relay apparatuses in the ring, instructing them to flush address information learned. The transmission of the flush packets may be performed by the data relay apparatus **300***a* and the data relay apparatus **300***b* that have moved to the dummy masters.

Referring to the ring **1** and the ring **3**, the health packets are blocked by the failure **32***a* to be prevented from going around. Therefore, the data relay apparatus **300***d* that is the master of the ring **1** and the data relay apparatus **300***i* that is the master of the ring **3** move to dummy masters according to the transition defined by the technology of Patent Literature 2. The user data packet cannot pass through the portion between the data relay apparatus **300***a* and the data relay apparatus **300***b*, but goes by way of the ring **2** to keep their connectivity. Therefore, the communication paths in the ring **1** and the ring **3** are not actually changed, which allows transmission of the flush packets to be eliminated in the ring **1** and the ring **3** (status **32**).

Thereafter, in order to decide which of the data relay apparatus **300***a* and the data relay apparatus **300***b* becomes the master, both of them transmit health packets to each other and compare their priorities with each other as described in Patent Literature 2 (status **33**).

In this example, as a result of exchanging the health packets, the data relay apparatus **300***a* moves to the master, and the data relay apparatus **300***b* moves to the transit. In the overall network, because the block **31***a* is maintained in the ring **1** and the block **31***b* is maintained in the ring **3**, the super loop is not formed. Moreover, the block **31***b* is released, and therefore, the ring **2** can be used as an alternative to the portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* where the failure occurs (status **34**).

When the failure is recovered, the health packets transmitted by the data relay apparatus **300***d* and the data relay apparatus **300***i* go around along the rings, and the data relay apparatus **300***d* and the data relay apparatus **300***i* return to the masters according to the transition defined by the technology of Patent Literature 2. Although the block **33***a* is present between the data relay apparatus **300***a* and the data relay apparatus **300***b*, the block **33***a* does not block the control packet but allows the control packet to pass through the port. The blocks do not move upon recovery, and therefore, there is no need to re-learn the address information (status **35**).

In the failure recovery method according to the present invention, one of the rings having the shared portion is set as the primary ring. If a failure occurs in the shared portion, the process of recovery is performed only on the primary ring to prevent formation of the super loop. Moreover, there is no need to allocate the roles such as the controller and the partner to the data relay apparatuses in the shared portion to prevent

formation of the super loop. The communication interruption due to re-learning of the address information occurs only once in the primary ring.

As is clear from the explanation, if the failure occurs in the shared portion, the data relay apparatus according to the present invention performs the process of recovery only on the primary ring, and performs basically the same operation as that of the failure recovery method of the Patent Literature 2 on any ring other than the primary ring. The status transition of the data relay apparatus according to the present invention is explained below.

FIG. **2** is a schematic for illustrating a status transition of a data relay apparatus. The data relay apparatus according to the present embodiment moves to four statuses such as "disable", "dummy master", "master", and "transit". At first, ports on both sides of the data relay apparatus are active in its disable status which indicates a breakdown status, and if at least one of the ports is linked up, the data relay apparatus moves to the dummy master (step **S1001**).

If the data relay apparatus has moved to the dummy master and both of the ports are linked up, the data relay apparatus exchanges the health packets with another data relay apparatus. As a result, if the data relay apparatus has a higher priority than the another data relay apparatus, it moves to the master (step **S1002**). If the data relay apparatus has a lower priority than the another data relay apparatus, it moves to the transit (step **S1003**). The exchange of the health packets is also performed when the flush packet is received after one of the links is down. The movement from the dummy master to the transit also occurs when the health packet is received from another master after the data relay apparatus moves to the dummy master due to timeout of the health packet.

When the data relay apparatus moves to the master and receives a health packet, from another data relay apparatus, having a higher priority than that of the data relay apparatus or receives a trap packet therefrom, the data relay apparatus moves to the transit (step **S1004**). If one of the links is down or if a timeout of the health packet occurs, the data relay apparatus moves to the dummy master (step **S1005**).

When it moves to the transit, if one of the links is down, the data relay apparatus moves to the dummy master (step **S1006**). If the links on both sides are down even in any status of the dummy master, the master, and the transit, the data relay apparatus moves to the disable (step **S1007**, step **S1008**, step **S1009**).

The configuration of the data relay apparatus according to the present embodiment is explained below. The data relay apparatus **300***a* and the data relay apparatus **300***b* shown in FIG. **1** have the same configuration as each other. Therefore, the data relay apparatus **300***a* is used as an example to be explained here. FIG. **3** is a block diagram of the configuration of the data relay apparatus **300***a* shown in FIG. **1**.

The data relay apparatus **300***a* includes ports **311***a* to **311***c*, a port **312***a*, control packet demultiplexers/multiplexers **321***a* to **321***c*, a control packet demultiplexer/multiplexer **322***a*, a main signal switch **330**, a control packet processor **340**, a ring controller **350**, and an address learning unit **360**.

The ports **311***a* to **311***c* are input-output communication ports on a non-shared side. Three ports are provided on the non-shared side as an example, but any number of ports may be provided. The port **312***a* is an input-output communication port on a shared side.

The control packet demultiplexers/multiplexers **321***a* to **321***c* and the control packet demultiplexer/multiplexer **322***a* are processors that demultiplex packets received by the ports **311***a* to **311***c* and the port **312***a* into the main signal and control packets, and that transmit the former one to a main signal switch **330** and the latter ones to the control packet processor **340**. The control packet demultiplexers/multiplexers **321***a* to **321***c* and the control packet demultiplexer/multiplexer **322***a* also multiplex the main signal output from the main signal switch **330** and the control packet output from the control packet processor **340** to be transmitted to a corresponding port.

The control packet mentioned here indicates a packet used to control a network, such as the trap packet, the health packet, and the flush packet. The main signal mentioned here indicates a packet other than the control packets i.e. a packet that stores user data or so.

The main signal switch **330** is a processor that decides a port, to which the main signal received by the ports **311***a* to **311***c* and the port **312***a* is forwarded, by referring to address information stored in an address-information storing unit **361** of the address learning unit **360**, and that outputs the main signal to the port that is decided as a destination.

The control packet processor **340** is a processor that processes the control packets, and includes a failure detector **341**, a trap packet processor **342**, a health packet processor **343**, a health packet storing unit **344**, and a flush packet processor **345**. The failure detector **341** is a processor that monitors a state of link, detects a failure, and notifies the processors of the failure.

The trap packet processor **342** is a processor that generates a trap packet and handles a trap packet received. The trap packet mentioned here indicates a packet used to notify other data relay apparatuses that a failure occurs in a line or a data relay apparatus of the same ring.

When receiving the notification to the effect that the failure is detected in the port on the shared side from the failure detector **341**, the trap packet processor **342** inquires the ring controller **350** as to which of the rings is the primary ring, and specifies the primary ring to generate a trap packet. When receiving the notification to the effect that the failure is detected in a port on the non-shared side, the trap packet processor **342** specifies the port where the failure is detected and generates a trap packet.

The process for receiving the trap packet is the same as that of Patent Literature 2. More specifically, if a data relay apparatus is the master of the ring where the trap packet is received, the relevant data relay apparatus causes the flush packet processor **345** to generate the flush packet, and then causes itself to move to the transit.

The health packet processor **343** is a processor that generates a health packet and handles a health packet received. The health packet mentioned here indicates a packet used to verify the connectivity of a ring. If there is a plurality of dummy masters or masters in the ring, the health packet is also used to select one out of these masters.

When the data relay apparatus of the health packet processor **343** is the master, the relevant health packet processor **343** specifies the relevant ring where the data relay apparatus is the master, and periodically generates a health packet. When the health packet transmitted does not return after a predetermined time passes, the health packet processor **343** causes the data relay apparatus to move to the dummy master.

When the data relay apparatus including the health packet processor **343** detects a failure and becomes the dummy master, the health packet processor **343** generates a health packet to select a master. The health packet processor **343** refers to priority information included in a health packet received from another data relay apparatus. If the priority of the data relay apparatus is higher than that of the another data relay apparatus, the health packet processor **343** causes the data relay apparatus to move to the master, or causes the data relay

apparatus to move to the transit if the priority of the data relay apparatus is lower than that of the another data relay apparatus.

The health packet processor **343** performs the processes based on the technology of Patent Literature 2 and also processes of caching a health packet transmitted from another data relay apparatus and outputting a copy of the health packet cached as necessary. The processes are explained below with reference to FIG. **1**. In the example shown in FIG. **1**, the status **32** shows a case where the line of the data relay apparatus **300***d* as the master of the ring **1** and the line of the data relay apparatus **300***i* as the master of the ring **3** are blocked by the failure **32***a*, the timeout of the health packets thereby occurs, and the data relay apparatuses **300***d* and **300***i* move to the dummy masters, respectively.

Since it is assumed that all the data relay apparatuses in FIG. **1** are devices based on the technology of Patent Literature 2, the data relay apparatus **300***d* and the data relay apparatus **300***i* only move to the dummy masters, and therefore they maintain the block **31***a* and the block **31***c*, respectively. However, if the ring **2** and the ring **3** are structured with devices based on EAPS or devices based on the technology of Patent Literature 1, the data relay apparatus **300***d* and the data relay apparatus **300***i* move to the transit due to the timeout of the health packets, and release the block **31***a* and the block **31***c*, respectively, resulting in formation of the super ring.

In order to prevent the formation, the health packet processor **343** caches the health packets received by the data relay apparatus for each ring, in the health packet storing unit **344**. If the data relay apparatus detects a failure in the shared portion and moves to the dummy master, the health packet processor **343** periodically transmits the copies of the health packets cached to the ring formed with the devices based on EAPS or based on the technology of Patent Literature 1. By transmitting the copies of the health packets in the above manner upon occurrence of the failure in the shared portion, the lines can be made to look like those that are not blocked by the failure, and formation of the super ring by the data relay apparatus **300***d* and the data relay apparatus **300***i* can be avoided.

In the explanation, the copies of the health packets are transmitted only to the ring structured with the devices based on EAPS or based on the technology of Patent Literature 1. However, the copies of the health packets may be transmitted to the ring structured with the devices based on the technology of Patent Literature 2. Furthermore, because the failure occurs in the shared portion, the control packet to instruct a data relay apparatus so as to prevent release of the block may be transmitted to the master of any ring other than the primary ring, instead of transmitting the copies of the health packets.

The flush packet processor **345** is a processor that generates a flush packet and handles a flush packet received. The flush packet mentioned here indicates a packet used to notify data relay apparatuses in the same ring so as to flush the address information learned and re-learn address information.

In the example shown in FIG. **1**, the flush packet is generated when the master receives the trap packet, but when the data relay apparatus detects a failure and moves to the dummy master, the relevant data relay apparatus can generate a flush packet. In this case, if a location where the failure occurs is the shared portion, the data relay apparatus generates the flush packets not for all the rings, but the flush packet processor **345** inquires the ring controller **350** as to which of the rings is the primary ring, and generates the flush packet only for the primary ring. By doing so, the communication interruption upon re-learning of the address information can be restricted only to the primary ring.

In the failure recovery method according to the present embodiment, only the primary ring that needs to re-learn address information upon occurrence of a failure in the shared portion is as explained above.

The ring controller **350** controls statuses of rings, and includes a ring-status storing unit **351**, a primary-ring selecting unit **352**, and a block setting unit **353**. The ring-status storing unit **351** stores information how normally the rings connected operate, and information based on which technology the ring is structured with data relay apparatuses. The ring-status storing unit **351** also stores a list of rings that can be selected as the primary ring. The primary-ring selecting unit **352** is a processor that selects a ring that becomes the primary ring based on the information stored in the ring-status storing unit **351**.

The primary ring is not fixed, and the primary-ring selecting unit **352** reselects a ring as the primary ring according to situations. Shifts of the primary ring are explained below using some examples. A case where a failure occurs in a non-shared portion of a primary ring is explained first. FIG. **4** is a schematic for explaining how to address a case where a failure occurs in a non-shared portion of a primary ring. The ring **2** is selected as an initial primary ring in the network having the same structure as that shown in FIG. **1** (status **40**).

Assume that a failure **32***b* occurs in a portion between the data relay apparatus **300***g* and the data relay apparatus **300***h* that is a non-shared portion of the ring **2**. The data relay apparatus **300***g* and the data relay apparatus **300***h* that detect the failure transmit trap packets to notify other data relay apparatus of occurrence of the failure (status **41**).

If another failure occurs in the shared portion, the ring **2** as the primary ring is in the middle of handling the failure **32***b* and cannot provide redundancy. Therefore, the data relay apparatus **300***a* and the data relay apparatus **300***b* shift the primary ring to another ring when receiving the trap packets from the primary ring. In the example shown in FIG. **4**, the data relay apparatus **300***a* and the data relay apparatus **300***b* receive the trap packets from the data relay apparatus **300***g* and the data relay apparatus **300***h* on the ring **2**, and select the ring **3** as a new primary ring (status **42**).

An example that failures occur in a shared portion and a non-shared portion of a primary ring is explained below. FIG. **5** is a schematic for explaining how to address a case where failures occur in the shared portion and the non-shared portion of the primary ring. A failure **32***c* occurs in a portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* that is the shared portion in the network having the same structure as that shown in FIG. **1**, and redundancy is provided by the ring **2** that is the primary ring (status **50**).

Assume that a failure **32***d* occurs in a portion between the data relay apparatus **300***g* and the data relay apparatus **300***h* that is a non-shared portion of the ring **2**. The ring **2** has already provided redundancy to response to the failure **32***c*, and therefore, the ring **2** cannot address the failure **32***d* if nothing is done.

Consequently, when receiving the trap packets from the primary ring in such a status that the redundancy is provided to the shared portion, the data relay apparatus **300***a* and the data relay apparatus **300***b* shift the primary ring to another ring (ring **3** in the example shown in FIG. **5**) where no failure occurs. In order to cause the ring that is a new primary ring to provide the redundancy to the shared portion, the data relay apparatus **300***a* and the data relay apparatus **300***b* transmit the trap packets to the relevant ring (status **51**).

As a result of the transmission, the failure **32***c* in the shared portion is handled by the ring **3** that is the new primary ring,

and the failure **32***d* in the non-shared portion is handled by the ring **2** that is the initial primary ring. The two failures are thereby processed without any trouble (status **52**).

An example that a plurality of shared portions is present in the primary ring is explained below. FIG. **6** is a schematic for explaining how to address a case where a plurality of shared portions is present in the primary ring. The network as shown in FIG. **6** is structured by adding a ring **4** to the network shown in FIG. **1**. The ring **4** includes data relay apparatuses **300***l*, **300***m*, **300***n*, **300***o*, and **300***p*, and the data relay apparatuses **3001** and **300***m* are shared by the ring **3**.

The ring **3** is set to be the primary ring in two shared portions, i.e., the portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* and a portion between the data relay apparatus **3001** and the data relay apparatus **300***m* (status **60**).

Assume that a failure **32***e* occurs in a portion between the data relay apparatus **300***j* and the data relay apparatus **300***k* that is a non-shared portion of the ring **3**. The data relay apparatus **300***j* and the data relay apparatus **300***k* that detect the failure transmit trap packets to notify other data relay apparatus of occurrence of the failure (status **61**).

At this time, if another failure occurs in either of the shared portions, the ring **3** as the primary ring is in the middle of handling the failure **32***e* and cannot provide redundancy. Therefore, the data relay apparatuses **300***a*, **300***b*, **3001**, and **300***m* shift the primary ring to another ring when receiving the trap packets from the primary ring.

In the example shown in FIG. **6**, the data relay apparatus **300***a* and the data relay apparatus **300***b* shift the primary ring to the ring **1**, while the data relay apparatus **3001** and the data relay apparatus **300***m* shift the primary ring to the ring **4** (status **62**). Since the two rings that are new primary rings have no failure, each of the two rings can provide redundancy if a failure occurs in the shared portion.

Another case that the shared portions are present in the primary ring is explained below. The network shown in FIG. **7** has the same structure as that of the network shown in FIG. **6**, and has two shared portions. More specifically, the ring **3** is the primary ring in both of the two shared portions that are the portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* and the portion between the data relay apparatus **3001** and the data relay apparatus **300***m* (status **70**).

Assume that a failure **32***f* occurs in the portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* that is the shared portion of the ring **3**. The data relay apparatus **300***a* and the data relay apparatus **300***b* that detect the failure transmit trap packets to notify other data relay apparatus of occurrence of the failure (status **71**).

At this time, if another failure occurs in the portion between the data relay apparatus **3001** and the data relay apparatus **300***m* that is the other shared portion, the ring **3** as the primary ring is in the middle of handling the failure **32***f* and cannot provide redundancy to the portion between the data relay apparatus **3001** and the data relay apparatus **300***m*. Therefore, the data relay apparatus **3001** and the data relay apparatus **300***m* shift the primary ring to another ring when receiving the trap packets from the primary ring.

In the example shown in FIG. **7**, the data relay apparatus **3001** and the data relay apparatus **300***m* have shifted the primary ring to the ring **4** (status **72**). Since the ring **4** that is a new primary ring has no failure, the ring **4** can provide redundancy to the shared portion if the failure occurs in the shared portion.

Even if the primary ring has the shared portions in the above manner, it is possible to handle the failure in the shared portion by re-selecting the primary ring to another ring in response to reception of the trap packet from the ring that is the primary ring.

As explained above, any ring where a failure occurs is not targeted for selection of a primary ring by the primary-ring selecting unit **352**. There is any ring that cannot be a target for selection of the primary ring. An example of this case is explained below.

FIG. **8** is a schematic for explaining how to address a case where there is a ring based on EAPS. The network shown in FIG. **8** has a multi-ring structure that shares the portion between the data relay apparatus **300***a* and the data relay apparatus **300***b* based on the ring **1** that includes the data relay apparatuses **300***a*, **300***b*, **300***c*, **300***d*, and **300***e*; the ring **2** that includes the data relay apparatuses **300***a*, **300***b*, **300***f*, **300***g*, and **300***h*; and a ring **3** that includes the data relay apparatuses **300***a*, **300***b* and data relay apparatuses **300***q*, **300***r*, and **300***s*.

Assume that the data relay apparatuses **300***q*, **300***r*, and **300***s* that form the ring **3** are data relay apparatuses based on EAPS. Because the data relay apparatuses based on EAPS have no function of re-selecting a master, the ring **3** cannot be changed to the primary ring. If there is a ring formed with data relay apparatuses based on EAPS in the ring having the shared portion, the ring is not a target for selection of the primary ring.

It is considered here about a case where all the rings are formed with data relay apparatuses based on EAPS. FIG. **9** is a schematic for explaining how to address a case where all the rings are based on EAPS. The network shown in FIG. **9** is structured with three rings such as the rings **1** to **3**. In the network, data relay apparatus other than the data relay apparatus **300***a* and the data relay apparatus **300***b* that are in the shared portion, are based on EAPS. The data relay apparatuses includes data relay apparatuses **300***t*, **300***u*, **300***v*, **300**×, **300***y*, **300***z*, and the data relay apparatuses **300***q*, **300***r*, and **300***s*.

If all the rings that are based on EAPS, none of the rings **1** to **3** becomes a target for selection of the primary ring. In such a network as above, however, another line is used to connect between the data relay apparatus **300***a* and the data relay apparatus **300***b* to structure a dummy ring that includes only the data relay apparatus **300***a* and the data relay apparatus **300***b*. This allows provision of redundancy to the shared portion.

Referring back to FIG. **3**, the block setting unit **353** is a processor that instructs the main signal switch **330** and the control packet processor **340** so as to set blocks for blocking a packet. More specifically, if a failure is detected in the non-shared portion, the block setting unit **353** issues an instruction to both the main signal switch **330** and the control packet processor **340** so as to block the packet of a port where the failure is detected. If a failure is detected in the shared portion, the block setting unit **353** issues an instruction only to the main signal switch **330** so as to block the packet of a port where the failure is detected and cause a control packet to pass through the port.

The address learning unit **360** is a processor that learns address information for control paths, and includes the address-information storing unit **361** and an address-information updating unit **362**. The address-information storing unit **361** is a storage that stores a pair of a port through which a packet is received and a source Media Access Control (MAC) address that is set in the packet, as address information.

The address-information updating unit **362** is a processor that updates address information in order to complete re-learning of address information in a short time. An example of

updating address information is explained below. FIG. **10** is a schematic for explaining how to update address information.

If a packet is transmitted from the data relay apparatus **300***e* to the data relay apparatus **300***k* in the status **30** shown in FIG. **1**, then the packet is transmitted through the data relay apparatuses **300***e*, **300***a*, **300***b*, and **300***k* (status **80**). If a packet is transmitted from the data relay apparatus **300***e* to the data relay apparatus **300***k* in the status **30** after the failure **32***a* occurs in the shared portion, then the packet is transmitted through the data relay apparatuses **300***e*, **300***a*, **300***f*, **300***g*, **300***h*, **300***b*, and **300***k* (status **81**).

In other words, before the failure **32***a* occurs, the packet is transmitted from the data relay apparatus **300***a* to the data relay apparatus **300***k* through the shared portion, while after the failure **32***a* occurs, the packet is transmitted from the data relay apparatus **300***a* to the data relay apparatus **300***k* through the ring **2** by going round the shared portion.

Referring to address information used when the data relay apparatus **300***a* decides a destination of a packet, address information before the failure **32***a* occurs is changed to another address information after the failure **32***a* occurs. More specifically, the address information indicates that a packet having a MAC address of A as a destination address is to be forwarded to a port connected to the shared portion, and the another address information indicates that the packet having the MAC address of A as a destination address is to be forwarded to a port connected to the ring **2**.

The address information for the data relay apparatus **300***a* is supposed to be changed in the above manner before and after the failure **32***a* occurs. That is, the address information indicating that the packet is forwarded to the port connected to the shared portion is supposed to be changed only to the address information indicating that the packet is forwarded to the port connected to the primary ring. The address-information updating unit **362** uses this principle and updates address information, when a failure occurs in the shared portion, so that the address information indicating that the packet is forwarded to the port connected to the shared portion is changed to the address information indicating that the packet is forwarded to the port connected to the primary ring. This update allows the time required for re-learning the address information to be reduced.

More specifically, in the status **30** shown in FIG. **1**, the data relay apparatus **300***a* receives the flush packet and is instructed so as to re-learn address information. The address-information updating unit **362** does not re-learn address information and updates so that the address information indicating that the packet is forwarded to the port connected to the data relay apparatus **300***b* is changed to the address information indicating that the packet is forwarded to the port connected to the data relay apparatus **300***f*. This process requires only updating of information stored in the address-information storing unit **361**. Therefore, the process is completed in a very short time, and a period when communication interruption occurs is extremely reduced.

The explanation is provided so far based on the case where two data relay apparatuses are present in the shared portion. However, even if three or more data relay apparatuses are provided in the shared portion, the failure recovery method according to the present embodiment is useful. FIG. **11** is a schematic for explaining a failure recovery operation when three or more data relay apparatuses are provided in the shared portion.

The network shown in FIG. **11** has a multi-ring structure that shares a portion including three data relay apparatuses **400***a*, **400***b*, and **400***c* based on a ring **1** that includes the data relay apparatuses **400***a*, **400***b*, and **400***c* and data relay apparatuses **400***d*, **400***e*, and **400***f*; a ring **2** that includes the data relay apparatuses **400***a*, **400***b*, and **400***c* and data relay apparatuses **400***g*, **400***h*, and **400***i*; and a ring **3** that includes the data relay apparatuses **400***a*, **400***b*, and **400***c* and data relay apparatuses **400***j*, **400***k*, and **400***l*.

The data relay apparatuses **400***a*, **400***b*, and **400***c* situated in a shared portion are data relay apparatuses that execute the failure recovery method according to the present embodiment of the present invention. The other data relay apparatuses are ones that perform failure recovery based on the technology of Patent Literature 2.

In normal operation, the data relay apparatus **400***e* that is a master of the ring **1** sets a block **41***a* in a port thereof on the side of the data relay apparatus **400***f*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **400***g* that is a master of the ring **2** sets a block **41***b* in a port thereof on the side of the data relay apparatus **400***h*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring. Likewise, the data relay apparatus **400***j* that is a master of the ring **3** sets a block **41***c* in a port thereof on the side of the data relay apparatus **400***a*, and causes a health packet to go around from a port on the opposite side to verify the connectivity of the ring (status **90**).

Assume that a failure **42***a* occurs in a portion between the data relay apparatus **400***a* and data relay apparatus **400***b* that is a shared portion. The data relay apparatus **400***a* detects the failure **42***a* and determines whether the failure occurs in the shared portion. If it is determined that the failure occurs in the shared portion, the data relay apparatus **400***a* sets a block **43***a* in a port on the side of the shared portion and transmits a trap packet only from a port, out of ports on the opposite side to the shared portion, connected to the ring **2** that is a primary ring. Likewise, the data relay apparatus **400***b* also sets a block **43***b* in a port on the side of the shared portion, specifies the ring **2**, and transmits a trap packet from the port on the opposite side to the shared portion. The block **43***a* and the block **43***b*, which are set in the shared portion, block a user data packet but allow a control packet such as a health packet to pass through the ports.

The data relay apparatus **400***a* and the data relay apparatus **400***b* move to dummy masters after transmission of the trap packets. The movement of the data relay apparatus that detects a failure to the dummy master after the transmission of the trap packet thereby is normal operation when the failure recovery is performed based on the technology of Patent Literature 2 (status **91**).

When receiving the trap packet, the data relay apparatus **400***g* that is the master of the ring **2** releases the block **41***b* to recover the failure, and then moves to the transit. The movement of the master to the transit when receiving the trap packet is normal operation when the failure recovery is performed based on the technology of Patent Literature 2.

The release of the block **41***b* causes a communication path to be changed. Therefore, the data relay apparatus **400***g* transmits flush packets to the data relay apparatuses in the ring, instructing them to flush address information learned. The transmission of the flush packet may be performed by the data relay apparatus **400***a* and the data relay apparatus **400***b* that have moved to the dummy masters (status **92**).

Referring to the ring **1** and the ring **3**, the health packets are blocked by the failure **42***a* to be prevented from going around. Therefore, the data relay apparatus **400***e* that is the master of the ring **1** and the data relay apparatus **400***j* that is the master of the ring **3** move to dummy masters according to the transition defined by the technology of Patent Literature 2. The

user data packet cannot pass through a portion between the data relay apparatus **400***a* and the data relay apparatus **400***b*, but goes along the ring **2** to keep their connectivity. Therefore, the communication paths in the ring **1** and the ring **3** are not actually changed, which causes transmission of the flush packet to be eliminated in the ring **1** and the ring **3** (status **93**).

Thereafter, in order to decide which of the data relay apparatus **400***a* and the data relay apparatus **400***b* becomes the master, both of them transmit health packets to each other and compare their priorities with each other as described in Patent Literature 2.

In this example, as a result of exchanging the health packets, the data relay apparatus **400***a* moves to the master, and the data relay apparatus **400***b* moves to the transit. In the overall network, because the block **41***a* is maintained in the ring **1** and the block **41***c* is maintained in the ring **3**, the super loop is not formed. Moreover, the block **41***b* is released, and therefore, the ring **2** can be used as an alternative to the portion between the data relay apparatus **400***a* and the data relay apparatus **400***b* where the failure occurs (status **94**).

When the failure is recovered, the health packets transmitted by the data relay apparatus **400***e* and the data relay apparatus **400***j* go around along the rings, and the data relay apparatus **400***e* and the data relay apparatus **400***j* return to the masters according to the transition defined by the technology of Patent Literature 2. Although the block **43***a* is present between the data relay apparatus **400***a* and the data relay apparatus **400***b*, the block **43***a* does not block the control packet but allows the control packet to pass through the port. The blocks do not move upon recovery, and therefore, there is no need to re-learn the address information (status **95**).

Even if three or more data relay apparatuses are provided in the shared portion, the failure recovery method according to the present embodiment effectively functions. Furthermore, in order to prevent formation of a super loop, there is no need to allocate the roles such as the controller and the partner to the data relay apparatuses in the shared portion, and the communication interruption due to re-learning of address information occurs only once in the primary ring.

A configuration of the data relay apparatus **400***b* situated in the middle of the shared portion is explained below. FIG. **12** is a block diagram of the configuration of the data relay apparatus **400***b* shown in FIG. **11**. The configuration of the data relay apparatus **400***b* is identical to the data relay apparatus **300***a* shown in FIG. **3** except that the data relay apparatus **400***b* has only a pair of a port and a control packet demultiplexer/multiplexer unlike the data relay apparatus **300***a* that has three pairs thereof corresponding to the rings **1** to **3**.

Process procedures for the data relay apparatus that implements the failure recovery method according to the present embodiment are explained below. Herein, only some of the process procedures specific to the failure recovery method according to the present embodiment are explained, and the process procedures described in Patent Literature 1 and Patent Literature 2 are omitted.

FIG. **13** is a flowchart of process procedures for a case where a failure is detected. If a failure is detected in a network (step S**101**), it is checked whether a location where the failure occurs is the shared portion (step S**102**).

If the failure occurs in the shared portion (step S**102**, Yes), a trap packet is transmitted to the primary ring (step S**103**). If the failure occurs not in the shared portion (step S**102**, No), the trap packet is transmitted to a ring where the failure is detected (step S**104**).

FIG. **14** is a flowchart of process procedures for a case where the trap packet is received. If the trap packet is received (step S**201**), it is checked whether the trap packet is transmitted from the primary ring (step S**202**).

If the trap packet is received from the primary ring (step S**202**, Yes), a new ring is selected from a list of rings that are stored in the ring-status storing unit **351** and that are selectable as a primary ring (step S**203**), and the primary ring is changed to the ring selected (step S**204**).

The ring as a source of the trap packet is excluded from the list of the rings irrespective of whether the trap packet is transmitted from the primary ring (step S**205**).

FIG. **15** is a flowchart of process procedures for a case where a health packet is received. If a health packet is received (step S**301**), it is checked whether the health packet is transmitted from a ring that is selectable (step S**302**).

If the ring as a source of the health packet is not included in the list of the rings (step S**302**, No) and the ring is a ring in which the master can move, i.e., a ring that includes data relay apparatuses based on the technology of Patent Literature 1 or the technology of Patent Literature 2 (step S**303**, Yes), then the ring as the source is added to the list of the rings (step S**304**).

In the present embodiment, as explained above, when a failure occurs in the shared portion, the trap packet is transmitted only to a preset primary ring, thus, avoiding formation of a super loop without allocating the roles such as the controller and the partner to the data relay apparatuses.

Furthermore, even if the flush packet instructing a data relay apparatus to flush address information for path control is transmitted in response to reception of the trap packet, a range affected thereby is restricted to the primary ring, which allows suppression of communication interruption due to re-learning of the address information to a minimum.

According to one aspect of the present invention, when a failure occurs in the shared portion, the failure notification packet is transmitted only to one redundancy-providing ring which is preset and provides redundancy. Therefore, it is possible to avoid formation of a super loop without allocating the roles such as the controller and the partner to the data relay apparatuses.

With this configuration, even if the flush request packet instructing a data relay apparatus to flush address information for path control is transmitted in response to reception of the failure notification packet, a range affected thereby is restricted to the redundancy-providing ring. Thus, it is possible to suppress the communication interruption due to re-learning of the address information to a minimum.

Furthermore, when a failure occurs in the shared portion, a hello packet previously stored is periodically transmitted. Thus, it is possible to avoid formation of the super loop due to release of the block when a timeout of the hello packet occurs.

Moreover, when a failure occurs in the shared portion, a packet is transmitted to instruct a ring other than the redundancy-providing ring so as not to release the block. Thus, it is possible to avoid formation of the super loop due to release of the block when a timeout of the hello packet occurs.

Furthermore, when the address information for path control needs to be flushed in accordance with occurrence of the failure in the shared portion, a flush request packet is transmitted only to the redundancy-providing ring. Thus, it is possible to suppress the communication interruption due to re-learning of the address information to a minimum.

Moreover, when the address information for path control needs to be re-learned in accordance with occurrence of the failure in the shared portion, by updating existing address information instead of re-leaning it from the beginning, the same effect can be obtained. Thus, it is possible to suppress

the time of communication interruption due to re-learning of the address information to a minimum.

Furthermore, when a failure occurs in the redundancy-providing ring, another ring is set as a new redundancy-providing ring. Thus, it is possible to reliably recover the failure in the shared portion even if a failure occurs in a non-shared portion.

Moreover, a ring where a failure occurs is excluded from selection candidates for the redundancy-providing ring. Thus, it is possible to recover the failure by a ring that can surely provide redundancy when a failure occurs in a shared portion.

Furthermore, a ring is checked that no failure occurs therein by receiving the hello packet, and then the ring is added to selection candidates for the redundancy-providing ring. Thus, it is possible to recover the failure by a ring that can surely provide redundancy when a failure occurs in a shared portion.

Moreover, a ring that is controlled by a different failure recovery method is excluded from selection candidates for the redundancy-providing ring. Thus, it is possible to recover the failure in a network where rings are controlled by different failure recovery methods.

Although the invention has been described with respect to a specific embodiment for a complete and clear disclosure, the appended claims are not to be thus limited but are to be construed as embodying all modifications and alternative constructions that may occur to one skilled in the art that fairly fall within the basic teaching herein set forth.

What is claimed is:

1. A data relay apparatus that recovers a failure in a network having a shared portion that is shared by a plurality of rings, relays a packet in the shared portion, and avoids occurrence of a loop path by setting at a portion other than the shared portion on each of the rings a block that blocks the packet and passes through a control packet used to control the network, the data relay apparatus comprising:

a failure detecting unit to detect a failure in the network;

a ring selecting unit to select from the rings a ring in which a failure is not detected by the failure detecting unit as a redundancy-providing ring used to provide redundancy for the shared portion;

a transmitting unit to transmit, to only a data relay apparatus on the redundancy-providing ring selected from among a plurality of data relay apparatuses on the rings that relay the packet in the portion other than the shared portion on each of the rings, a trap packet that makes each of the data relay apparatuses release the block as the control packet, when the failure detecting unit detects a failure in the shared portion;

a block setting unit to set the block at a port connected to the shared portion, wherein

the ring selecting unit selects the redundancy-providing ring from the rings other than a ring whose portion except for the shared portion includes a failure detected by the failure detecting unit.

2. The data relay apparatus according to claim **1**, further comprising:

a hello-packet storing unit to store a hello packet received; and

a hello-packet transmitting unit to transmit, when the failure is detected by the failure detecting unit, the hello packet stored in the hello-packet storing unit at a predetermined interval.

3. The data relay apparatus according to claim **1**, further comprising a control-packet transmitting unit to transit, when the failure is detected by the failure detecting unit, the control packet to a data relay apparatus that sets the block in a ring other than the redundancy-providing ring selected so as not to release the block.

4. The data relay apparatus according to claim **1**, further comprising a flush-request-packet transmitting unit to transmit, when the failure is detected by the failure detecting unit, a flush request packet to the redundancy-providing ring selected to flush address information for path control.

5. The data relay apparatus according to claim **1**, further comprising an address-information updating unit to update, when the failure is detected by the failure detecting unit and when address information for path control needs to be updated, the address information, so that a packet that is supposed to be output to the port where the failure is detected by the failure detecting unit is output to a port connected to the redundancy-providing ring selected.

6. The data relay apparatus according to claim **1**, wherein the redundancy-providing-ring selecting unit selects, when the redundancy-providing ring selected receives a failure notification packet, another ring that shares the shared portion as a new redundancy-providing ring.

7. The data relay apparatus according to claim **6**, wherein when a ring other than the redundancy-providing ring selected receives the failure notification packet, the redundancy-providing ring selecting unit excludes the ring from selection candidates for the redundancy-providing ring.

8. The data relay apparatus according to claim **6**, wherein when a ring other than the redundancy-providing ring selected receives the hello packet, the redundancy-providing ring selecting unit adds the ring to selection candidates for the redundancy-providing ring.

9. The data relay apparatus according to claim **6**, wherein the redundancy-providing ring selecting unit excludes a ring that shares the shared portion but is controlled by a different failure recovery method from selection candidates for the redundancy-providing ring.

10. A failure recovery method for a data relay apparatus that recovers a failure in a network having a shared portion that is shared by a plurality of rings, relays a packet in the shared portion, and avoids occurrence of a loop path by setting at a portion other than the shared portion on each of the rings a block that blocks the packet and passes through a control packet used to control the network, the method comprising:

detecting a failure in the network;

selecting from the rings a ring in which a failure is not detected at the detecting as a redundancy-providing ring used to provide redundancy for the shared portion;

transmitting, to only a data relay apparatus on the redundancy-providing ring selected from among a plurality of data relay apparatuses on the rings that relay the packet in the portion other than the shared portion on each of the rings, a trap packet that causes each of the data relay apparatuses to release the block as the control packet, when the detecting detects a failure in the shared portion; and

setting the block at a port connected to the shared portion, wherein

the selecting includes selecting the redundancy-providing ring from the rings other than a ring whose portion except for the shared portion includes a failure detected at the detecting.

11. The failure recovery method according to claim 10, further comprising:

storing a hello packet received; and

transmitting, when the failure is detected at the detecting, the hello packet stored at the storing at a predetermined interval.

12. The failure recovery method according to claim 10, wherein the transmitting includes transmitting, when the failure is detected at the detecting, the control packet to a data relay apparatus that sets the block in a ring other than the redundancy-providing ring selected so as not to release the block.

13. The failure recovery method according to claim 10, further comprising transmitting, when the failure is detected at the detecting, a flush request packet to the redundancy-providing ring selected to flush address information for path control.

14. The failure recovery method according to claim 10, further comprising updating, when the failure is detected at the detecting and when address information for path control needs to be updated, the address information, so that a packet that is supposed to be output to the port where the failure is detected at the detecting is output to a port connected to the redundancy-providing ring selected.

15. The failure recovery method according to claim 10, wherein the selecting includes selecting, when the redundancy-providing ring selected receives a failure notification packet, another ring that shares the shared portion as a new redundancy-providing ring.

16. The failure recovery method according to claim 15, wherein when a ring other than the redundancy-providing ring selected receives the failure notification packet, the selecting includes excluding the ring from selection candidates for the redundancy-providing ring.

17. The failure recovery method according to claim 15, wherein when a ring other than the redundancy-providing ring selected receives the hello packet, the selecting includes adding the ring to selection candidates for the redundancy-providing ring.

18. The failure recovery method according to claim 15, wherein the selecting includes excluding a ring that shares the shared portion but is controlled by a different failure recovery method from selection candidates for the redundancy-providing ring.

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